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SYNERGY IN THE JOINT CONVENTIONAL STRIKE FORCE

by

Steven M. Williams

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Thesis Advisor: Gregory G. Hildebrandt

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This thesis analyses the synergy among components of the joint conventional strike force in order to determine the most effective force structure. The analysis begins by constructing a conceptual model of military decision behavior within the context of force structure decisions, using the two primary roles of the military, deterrence and warfighting. From the model, synergistic relationships are identified which are later exploited. The joint force components used in the analysis are aircraft carriers, surface combatants with Tomahawk cruise missiles, and long-range bombers. Procurement and operating costs are estimated for the individual components, then combined into three equal-cost joint forces with varying numbers of naval groups and bombers. A qualitative assessment of the ability of each joint force to deter conflict is made. Then, using a stylized scenario, the analysis quantifies warfighting effectiveness, both with and without considering attrition. However, total effectiveness is not a simple additive solution of deterrence and warfighting. The effects of synergy also must be weighed. The analysis concludes that a balanced joint force structure of both naval groups and bombers produces the greatest effectiveness.

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SYNERGY IN THE JOINT CONVENTIONAL STRIKE FORCE

Steven M. Williams
Lieutenant, United States Navy
B.S., Marquette University, 1989

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Author: ______________________________
Steven M. Williams

Approved by: ______________________________
Gregory G. Hildebrandt, Thesis Advisor

____
Wayne P. Hughes, Second Reader

____
Peter Purdue, Chairman
Department of Operations Research

ABSTRACT

This thesis analyses the synergy among components of the joint conventional strike force in order to determine the most effective force structure. The analysis begins by constructing a conceptual model of military decision behavior within the context of force structure decisions, using the two primary roles of the military, deterrence and warfighting. From the model, synergistic relationships are identified which are later exploited. The joint force components used in the analysis are aircraft carriers, surface combatants with Tomahawk cruise missiles, and long-range bombers. Procurement and operating costs are estimated for the individual components, then combined into three equal-cost joint forces with varying numbers of naval groups and bombers. A qualitative assessment of the ability of each joint force to deter conflict is made. Then, using a stylized scenario, the analysis quantifies warfighting effectiveness, both with and without considering attrition. However, total effectiveness is not a simple additive solution of deterrence and warfighting. The effects of synergy also must be weighed. The analysis concludes that a balanced joint force structure of both naval groups and bombers produces the greatest effectiveness.

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EXECUTIVE SUMMARY

With the Cold War ended, the U.S. has lost a well-defined enemy in the Soviet Union. Regional conflicts are the bane of peace in the foreseeable future. In this new environment, the military services have each been aggressively defining their respective roles and missions. In support of this, several recent studies have examined the future of air power, particularly naval aircraft and long-range bombers. However, with joint operations becoming a peacetime role in addition to its traditional role in war, solidarity is crucial. Rather than focusing on differences between weapons systems, attention should be directed toward the synergy among forces, how they can be used more effectively together. This synergy needs to be analyzed with consideration for the roles and objectives of the entire military structure.

The military has two primary roles, deterrence of aggression and winning wars when deterrence fails. Deterrence significantly depends on forces visibly present in a region, notably naval forces. Winning wars requires a military that can respond rapidly and project sufficient strength against an aggressor. With a budget constraint, the nation cannot build a military structure that maximizes the effectiveness of each role. Instead, some reduction in effectiveness with respect to each role must be accepted, while relying on synergistic effects among force components that increase total force effectiveness.

Synergy among military forces exists on two levels, strategic and tactical. Strategically, deployed naval forces engaged in presence act as a visible representation of all military forces. Likewise, warfighting effectiveness acts as a force multiplier in improving deterrence effectiveness. Tactical synergy comes in many flavors. Deployed forces form the leading edge of rapid response forces. Further, military components, in their operating methods, increase warfighting effectiveness beyond what each individual component could do alone. In force structure decisions, simply making tradeoffs of weapons systems is not sufficient. The military must also capture the synergistic effects.

We analyzed the deterrence and warfighting effectiveness for the joint conventional strike force, the components of which are aircraft carriers and their airwings, naval combatants with Tomahawk missiles, and long-range bombers. The procurement and

operating costs of the individual elements were estimated, then assembled into three joint forces of equal cost. The three carrier quantities used are 14, 10 and 6. As the quantity of carriers decreases, more bombers are acquired.

For each joint force, we subjectively assessed deterrence effectiveness. We conclude that as the number of carriers declines, deterrence effectiveness diminishes. However, warfighting effectiveness may increase, offsetting the loss in deterrence.

Warfighting effectiveness was quantified using a scenario based in Southwest Asia. Force effectiveness was calculated both with and without attrition to U.S. forces. Effectiveness was measured by the number of targets destroyed, and the number of aircraft sorties. The latter measure of effectiveness is a proxy for the responsiveness and coverage of targets by strike assets. Carrier aircraft were shown to be far more effective in producing sorties, while bombers hold the edge in number of targets destroyed. Deciding on which force structure has more warfighting effectiveness depends on which measure holds more importance. However, there is more than a tradeoff between deterrence and warfighting. The effects on synergy also must be considered.

A joint force structure with an emphasis on carriers has the best deterrence. But its warfighting effectiveness declines because sufficient bombers do not exist to destroy a large number of targets quickly. Expecting carrier aircraft to accomplish this mission exposes them to significant attrition risks. Placing a heavy reliance on bombers results in some loss in deterrence, but a significant number of targets can be hit very quickly. However, the bombers also are exposed to attrition risks due to the reduction in strike support provided by carriers. Therefore, we conclude that a balanced force, with a sufficient number of bombers and carriers, has the necessary synergy to be effective.

I. INTRODUCTION

> In the final analysis, our armed forces must be prepared to respond rapidly, to deter, and, if necessary, to fight and win.... (*National Security Strategy*, 1993).

The Cold War symbolically ended with the destruction of the Berlin Wall. As has been the case after every war, debate is centered on the size and shape of the future military forces. The threat of major war is greatly diminished, allowing for a smaller number of forces. However, without the threat of Soviet domination, ethnic and racial hatred has been released. Regional conflicts are the bane of peace in the foreseeable future. Without a well defined enemy, the services have each been aggressively defining their respective roles and missions in the new defense posture. To add to the clutter, the Department of Defense now emphasizes jointness in both warfare and peacetime planning.

> Defense of our nation is the fundamental basis for military service and joint warfare is indispensable to that defense. The reason for our existence demands unity in our efforts. (Powell, 1991, p. 2)

The most notable debate concerns air power -- land-based tactical aircraft, long-range bombers, and naval aircraft. Several studies have been conducted espousing the virtues of each.

In response to a report by the Senate Armed Services Committee (SASC), the Center for Naval Analyses (CNA) in December 1991 released an information memorandum comparing long-range bombers and naval forces (Perin 1991). The study examined the missions of carrier battle groups (CVBGs) and bombers. It concluded that because a CVBG has multiple capabilities in both peace and crises, whereas bombers are primarily designed for strike warfare, a direct comparison of the two is not possible. However, some comparisons can be made between tactical aircraft in the carrier air wing (CVW) and bombers in the common mission of strike warfare. Using the proposed A-X aircraft and B-2, equal cost forces were assembled. Then, using a variety scenarios, payload delivered was calculated. Despite the B-2s larger payload, the A-X delivered comparable or greater payload over the

course of a campaign due to its higher sortie rate. The report emphasized aircraft differences which, unfortunately, detracted from the more important identification of complementary and synergistic relationships. Perin concluded by noting "... the U.S. derives many advantages from balanced aviation forces that maintain a degree of tactical and operational complementarity " (Perin, p 57).

On June 17, 1992, Donald Rice, Secretary of the Air Force, testifying before the SASC, presented the *USAF Bomber Roadmap* white paper (Rice, 1992). The Roadmap outlines the strengths of the bomber forces and identifies planned upgrades in survivability and conventional weapons capabilities for the B-1B, B-2A and B-52H. To demonstrate the significance of the upgrades, a hypothetical list of 238 high priority targets to be destroyed in the first 5 days of a conflict was identified. These targets broke down into 1250+ aimpoints. The bomber force of B-1B and B-52H in 1992 could hit only 300 of the aimpoints. By 2001, with the B-2A and improved B-1B and B-52H, all 1250+ aimpoints could be hit in the first 5 days. By combining the B-2A's stealth with standoff weapons, the highest threat defenses can be penetrated, allowing other bombers to strike against low and medium threat defenses. Should a second contingency arise, the bomber force has the capability to quickly swing to the other theater and strike priority targets until additional forces arrive. The paper states that

> ...bombers have inherent strengths no other weapon system can match. Their combination of range, payload and flexibility make bombers the theater commander's weapon of choice for both crises response and sustained operations. (Rice, 1992)

With joint operations becoming a peacetime role in addition to its traditional role in war, solidarity is crucial. Analysis tends to focus on differences between weapons systems, and why one is preferred over another. Instead, attention should be directed toward the synergy between forces, as Perin recognized but did not explore further. The nation's military needs both carriers and bombers. Emphasis needs to be placed not on the capabilities of singular assets, but on the objectives of the joint force.

In this thesis we analyze the tradeoffs between these joint objectives by focusing on the joint conventional strike force. In Chapter II, we identify the joint force objectives and their contributing factors. From these, a conceptual model of military decision behavior is

developed. It provides the framework from which comparisons and tradeoffs between alternative joint force structures can be drawn. In Chapter III, the components of the joint force are described and their costs estimated. Three equal cost joint forces are then constructed. Chapter IV calculates the capabilities of each force, from the context of the conceptual model of military decision behavior. Finally, Chapter V presents conclusions and recommendations for future study.

II. CONCEPTUAL MODEL

To begin, we must first define the strategic objectives of the military. The *National Military Strategy* in 1992 stated:

> The fundamental objective of America's armed forces will remain constant: to deter aggression and, should deterrence fail, to defend the nation's vital interests against any potential foe. Deterrence remains the primary and central motivating purpose underlying our national military strategy (p. 6).

Clearly, the objectives are deterrence and warfighting, with deterrence the more important of the two. In order to analyze these objectives we impose a structure on them using concepts from probability theory.

Deterrence is the capability to prevent or discourage some action, in this case war. Successful deterrence, therefore, reduces the probability of war, P(War). Defining the factors contributing to deterrence generates debate. However, two statements from the *National Military Strategy* provide an answer.

> Over the past 45 years, the day-to-day presence of US forces in regions vital to US national interests has been key to averting crises and preventing war... Although the numbers of US forces stationed overseas will be reduced, the credibility of our capability and intent to respond to crises will continue to depend on judicial forward presence (p. 7).

> Forward presence helps to reduce regional tensions, to deter potential aggressors, and to dampen regional arms competitions (p. 11).

Successful deterrence, therefore, relates functionally to forward presence.

$$P(\text{War}) = f(\text{presence})$$

The argument is not that only presence affects P(War), but that military strategy emphasizes its importance. Deterrence also depends on the entire structure of foreign relations and on the nation's military posture. Presence can take on many forms, from ground forces stationed overseas, to routine deployment of naval forces, or periodic training exercises with foreign powers. All forms send a signal of U.S. concern and involvement.

But the physical presence of military forces is not sufficient. They also rely on a strategic synergy with forces remaining in the continental U.S. (CONUS). To potential aggressors and allies alike, credible forces, visibly present, represent the totality of U.S. forces

which can be employed in a crises. However, vulnerable forces, or the absence of forces, would be interpreted as the lack of U. S. resolve and provide no deterrence. Admiral Owens states,

> In deterrence, however, the issue is what U.S. forces the potential aggressor thinks can get there sooner rather than later. Here, the visible proximity of deployed credible U.S. forces probably has great effect... Visible military presence can, of course, work against our capacity to deter a regional predator if, instead of being impressed with the "invulnerability" of the forces deployed overseas, the predator sees the forces as easy targets and believes the United States sees them as such also (Owens, 1994, p. 31).

Although fostering peace is the primary objective of the military, when deterrence fails, it must be prepared to fight and win. This is the second objective of military forces. When a crises erupts, the conditional probability of winning, given that war has occurred, P(Win | War), must be significant. The primary functional components of this objective are more easily defined. "We must be able to project power... rapidly and in sufficient strength to defeat any aggressor who has not been deterred by our forward presence" (*National Military Strategy*, 1992, p. 11). Therefore,

$$P(\text{Win} \mid \text{War}) = g(\text{response time, strength}).$$

Together, the two military objectives yield the joint probability of war and winning.

$$P(\text{War and Win}) = P(\text{War}) * P(\text{Win} \mid \text{War}) \qquad (1)$$

However, evaluation of equation (1) is difficult. For example, if P(War) = 0, meaning peace is certain (a desirable outcome), then P(War and Win) = 0. Unfortunately, we obtain the same answer if P(Win | War) = 0, or certain loss (highly undesirable). Therefore, as shown in Figure 1, we use equation (1) to construct a conceptual model of military decision behavior and apply utility theory.

In the figure, a square represents some decision to be made. A circle represents the probabilistic outcome of that decision. Although the figure depicts two decisions, they are related by force structure and occur at the same time. In this model, a military decision maker chooses a force structure with some presence characteristics. If peace occurs, the decision maker obtains an arbitrarily chosen amount of 100 utils, a measure of utility. The chosen force structure also possesses some warfighting qualities. If war erupts, the military either loses,

yielding 0 utils, or wins, yielding q utils, an unknown level. We can make two assumptions about the model. First, the decision maker is rational and prefers winning over losing. He cannot earn negative utils from winning a war, therefore $q > 0$. The second assumption, peace is not certain and $P(War) > 0$.

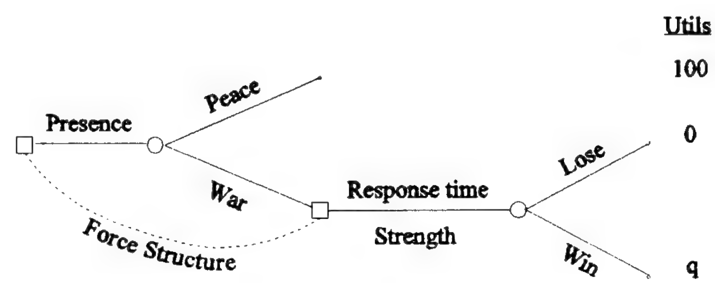


Figure 1. Conceptual military decision behavior model.

We now impose a limited defense budget on the decision maker. The military cannot build a force capable of providing both maximum presence and warfighting capabilities, relying instead on limited portions of each. The decision maker must chose a force structure which maximizes expected utility.

$$\text{Max } E(Util) = P(Peace)*U(Peace) + P(War)*P(Lose \mid War)*U(Lose) + P(War)*P(Win \mid War)*U(Win)$$

$$= P(Peace)*100 + P(War)*P(Win \mid War)*q \qquad (2)$$

The type of force to build now depends on the value of q. If q is sufficiently small, then the equation is maximized by focusing on deterrence and maximizing P(Peace). If $q > 100$, then the decision maker would prefer to wage war to peaceful negotiations and therefore maximize warfighting potential. If $q = 100$, the choice is ambiguous. However, q is not constant, varying by decision maker and time. Desert Shield/Storm is an example. Iraq

began preferring war, with $q > 100$. Initially, the U.S. preferred negotiations, $q < 100$, until the time deadline arrived, then it too chose war. The challenge for U.S. military decision makers, is to build a balanced force structure which recognizes an unknown q. The decision requires a recognition of the strategic and tactical synergy between presence forces and warfighting forces. Presence forces form the leading edge of the rapid response forces but lack sufficient strength to win the war alone. Warfighting forces provide that strength, and by increasing P(Win | War), further deters an aggressor. Cost is the limiting factor preventing both forces from achieving maximum potential.

We approach this problem by limiting our analysis to strike warfare in examining several joint force structures. A quantitative measurement of deterrence effectiveness is difficult, therefore we make a qualitative assessment. Warfighting capability is analyzed quantitatively, with a subjective appraisal of its influence on deterrence.

III. COST ESTIMATION

Many elements comprise the joint conventional strike force, nuclear aircraft carriers (CVNs) and their airwings (CVWs), naval surface combatants and submarines with Tomahawk cruise missiles (TLAM), Air Force long-range bombers and land-based tactical aircraft. To make the analysis manageable and meaningful, the issue of basing must be considered.

Naval forces enjoy freedom of the seas, giving them the ability to operate close to an aggressor's shore, with due consideration to their own safety. Although their speed is relatively slow, replenishment ships increase the capability to operate at sea for long durations and at greater ranges from friendly bases. Aircraft and TLAM provide the ability to project power from great distances while avoiding hostile weapons, normally from within hundreds of miles of the shore. Long-range bombers, as the name implies, can reach anywhere in the world within hours from the CONUS, provided sufficient aerial refueling exists. Large payloads makes them efficient over these great distances. With the availability of overseas bases, such as Guam or Diego Garcia, round-trip distances to many parts of the globe are considerably lessened. Land-based tactical aircraft can also benefit from overseas bases. But with their smaller payloads and shorter ranges they become inefficient. Like carrier aircraft, they are best used from airfields within hundreds of miles or less from the battle. This requires basing in the theater, which, at the outset of hostilities cannot be guaranteed. For this analysis, we only want to use forces which can be deployed quickly and fight without relying upon theater basing. Therefore, we consider a joint strike force to consist of CVN/CVWs, surface combatants with TLAM, and bombers.

First, we define the specific forces involved, then estimate their procurement and operating and support (O&S) costs. All dollar figures have been converted to constant fiscal year (FY) 1995 dollars using DOD deflators based on total obligational authority from *National Defense Budget Estimates for FY 1994* (1993). The Appendix lists costs by year for all forces used and contains more details on the cost components encompassed by procurement and O&S categories.

A. AIR FORCE COMPONENTS

1. Procurement Costs

The planned inventory of bombers for the near future includes the B-1B, B-2A and B-52H (Rice, 1992). Procurement costs for the B-1B and B-2A are broken out by year in *U.S. Military Aircraft Data Book* (Nicholas, 1977-1994). After converting to constant FY95 dollars, total dollars spent was averaged over the quantity of aircraft procured. This average was then annualized over the planned service life of the aircraft (Hildebrandt, 1985, p. 16), yielding an annualized procurement cost per aircraft. This cost, however, is not the annual cost to replace an aircraft because it does not account for production rates, learning curves, technological changes, and actual service life (Davis, 1993, p. 77).

The approach taken for the B-52H was different due to a lack of yearly data. Instead, an estimate of flyaway cost from *Military Cost Handbook* (Nicholas, 1994), was used. The average ratio of procurement cost to flyaway cost was computed for several aircraft types (Nicholas, 1977-1994). This average ratio was multiplied by the B-52H flyaway cost, and then annualized over the service life.

Three terms used to define the quantity of aircraft in inventory are primary aircraft authorized (PAA), backup aircraft inventory (BAI), and total aircraft inventory (TAI). PAA are those aircraft assigned to a unit for performance of operational missions (AFR 173-13, 1986, p. 139). BAI includes aircraft used to train new pilots, those used in research and development, or undergoing depot-level maintenance. TAI is simply PAA plus BAI. It is important, when estimating the cost of an aircraft squadron, that the costs associated with BAI are captured. Each aircraft's annualized procurement cost was multiplied by TAI and then divided by the number of squadrons. The values for B-1B and B-52H TAI are available from Air Force *VAMOSC*, and number of squadrons is contained in Nicholas (1994). B-2A TAI and squadron numbers were provided by Ritchey (1994).

2. Operating and Support Costs

B-1B and B-52H O&S costs were derived from Air Force *VAMOSC* data between 1990 and 1993. To conform this data to that provided by the Navy, indirect costs associated with base operating and support (BOS) were removed, then averaged by the number of

squadrons. We assume O&S costs do not increase over the service life of an aircraft. B-2A O&S costs were provided by Ritchey (1994), with no correction made for BOS. Table 1 summarizes all bomber aircraft inventory and cost data.

	TAI	PAA	Squadrons	Procurement	O&S	Total
B-1B	94	84	6	$ 256.934	$ 95.878	$ 352.812
B-2A	20	16	2	667.213	132.500	799.713
B-52H	94	84	6	63.847	96.561	160.408

Table 1. Annualized cost per squadron in millions of FY 95 dollars.

B. NAVAL COMPONENTS

1. Surface Forces

We are interested in surface forces which provide strike potential. The CVN-68 class is an obvious inclusion. Also, many ship classes carry TLAM. We limit the analysis to those ship classes with a vertical launch system (VLS), which are CG-47, DDG-51, and DD-963. To provide sustainability to these surface forces, we include an AOE-6 class fast combat support ship.

a. Procurement Costs

Yearly procurement costs for all surface forces is contained in *U.S. Weapon Systems Costs* (Nicholas, 1977-1994). The average procurement cost per ship in FY 95 dollars was calculated, then annualized by service life (Hildebrandt, 1985, p. 16). The CVN has an additional cost for nuclear refueling and overhaul (Hall, 1994). This cost is included in procurement costs.

b. Operating and Support Costs

Navy *VAMOSC* data on ship class averages from 1986 to 1993 was used. The data for the CVN-68 and CG-47 classes was used directly. Depot-level maintenance costs for the DD-963 are overstated due to a modernization program installing VLS. This cost category was adjusted by equating the ratio of DD-963 to CG-47 depot-level costs to the

ratio of intermediate-level maintenance costs. The DDG-51 class data contains only two observations from 1992 to 1993, with no depot level costs. Its intermediate level costs are very low compared to the CG-47 class, therefore, it is given the same amount of depot level spending as the DD-963 class. The AOE-6 class is new to the fleet and no cost data for it is available. We used O&S data for the AOE-1 class, which is of comparable size and cargo capacity. (*Jane's*, 1994) All ship cost data are contained in Table 2.

	Procurement	O&S	Total
CVN-68	$ 176.730	$ 165.551	$ 286.725
CG-47	42.631	28.017	70.648
DDG-51	29.893	20.709	50.602
DD-963	15.059	22.352	37.411
AOE-6	16.875	38.320	55.195

Table 2. Annualized cost per ship in millions of FY 95 dollars.

2. Tomahawk

The procurement costs for TLAM is from *U.S. Missile Data Book* (Nicholas, 1994). The total procurement dollars spent was averaged over the total missiles bought, and then annualized over the service life (Hildebrandt, 1985, p. 16). There is no associated O&S cost. The annualized cost per missile, in millions of FY 95 dollars is $ 0.241. The notional number of missiles per ship (Davis, 1993, p. 35) is listed in Table 3.

	TLAM
CG-47	30
DDG-51	22
DD-963	54

Table 3. Notional TLAM carried per ship.

3. Aircraft

a. Procurement Costs

The future CVW contains many of the same types of aircraft as today's, but with a greater emphasis on multi-role aircraft. The mix we use combines aspects from *Sortie Generation Factors* (1994) and *Navy Carrier Battle Groups* (Davis, 1993) and includes the F-14D, F/A-18E/F, EA-6B, S-3, E-2C, and SH-60F. Surface combatants also carry helicopters, the SH-60B, and replenishment ships use the CH-46 helicopter. Procurement costs for all aircraft except the CH-46 are broken out by year in *U.S. Military Aircraft Data Book* (Nicholas, 1977-1994), using the most current aircraft variant. Average procurement cost was annualized over the planned service life of the aircraft (Pierrot, 1987, p. 40).

The approach for the CH-46 was similar to that used for the B-52H, due to a lack of yearly data. An estimate of flyaway cost from *Military Cost Handbook* (Nicholas, 1994) was used. The average ratio of procurement cost to flyaway cost was computed for several helicopter types, applied to the CH-46 flyaway cost, and then annualized over the service life.

To determine TAI, the Navy uses the following formula (Pierrot, 1985, p. 38).

$$\begin{aligned} TAI &= PAA + Training + RDT\&E + Backup \qquad (3) \\ \text{where: } Training &= .25 * PAA \\ RDT\&E &= .03 * PAA + Training \\ Backup &= .15 * PAA + Training + RDT\&E \end{aligned}$$

In Equation 3, the PAA per CVW is used, which yields the TAI needed to support an airwing. The annualized procurement cost was multiplied by TAI for the cost per airwing. The SH-60B PAA level assumes that each surface combatant carries one helicopter. Each replenishment ship operates with two CH-46s.

b. Operating and Support Costs

All O&S costs are obtained from Navy *VAMOSC* data between 1986 and 1993. The average cost over this time period was divided by the average quantity of aircraft in inventory. The average cost per aircraft was then multiplied by TAI. Table 4 summarizes all data.

	TAI	PAA	Procurement	O&S	Total
F-14D	20.73	14	$ 115.383	$ 37.270	$ 152.654
F/A-18E/F	53.30	36	150.581	112.468	263.049
EA-6B	5.92	4	17.973	25.810	43.783
S-3	11.85	8	21.080	44.288	65.368
E-2C	5.92	4	25.182	23.317	48.499
SH-60F	8.88	6	7.754	23.533	31.287
SH-60B	1.48	1	2.137	3.807	5.944
CH-46	2.96	2	0.142	23.480	23.622

Table 4. Annualized aircraft costs in millions of FY 95 dollars.

4. Naval Groups

A great strength of naval forces is their flexibility in forming forces packages to counter any threat. Voss (1991) described the structure of several naval force options, and their respective strengths and weaknesses. We use two of these groups, a carrier battle group (CVBG) and a cruiser task group (CGTG). The CVW consists of the aircraft described above. Each surface combatant carries one SH-60B and each AOE has two CH-46. The notional number of TLAM per ship is doubled to allow for wartime reserves. Table 5 lists the structure of each group and its respective total annualized costs.

	CVBG	CGTG
CVN-68	1	
CVW	1	
CG-47	1	1
DDG-51	2	1
DD-963	2	1
AOE-6	1	1
SH-60B	5	3
CH-46	2	2
TLAM	364	212
Total Cost	$ 1334.160	$ 306.321

Table 5. Naval group components and total annualized cost in millions of FY 95 dollars.

C. JOINT FORCE STRUCTURES

The joint strike force structure includes the Air Force and Naval components described. The number of naval groups remains constant in order to provide an undeviating quantity, but not necessarily quality, of presence. Each force has a total of 14 naval groups, containing 14, 10, and 6 CVBGs, and 0, 4, an 6 CGTGs, respectively. The number of bombers changes with respect to the level of CVBGs. As the number of CVBGs decreases, more bomber squadrons are purchased, maintaining an equal cost for all three joint structures. This is depicted in Table 6. The number of bomber squadrons in JF2 and the number of CVNs are closest to current levels. A consistent change in bombers between forces is maintained. All costs are within 99 percent of equality.

	JF1	JF2	JF3
CVBG	14	10	6
CGTG	0	4	8
B-1B	1	6	11
B-2A	0	2	4
B-52H	1	6	11
Total Cost	$ 19,191.455	$ 19,245.625	$ 19,299.795

Table 6. Equal cost joint strike force structures in millions of FY 95 dollars.

IV. FORCE EFFECTIVENESS

A. DETERRENCE

Each of the three joint forces has some deterrence characteristics, which we have already defined as significantly dependent on presence. Although bombers can participate in presence missions, such as training exercises, naval forces represent the most significant contributor. There are two aspects to presence, the quantity and quality of forces.

The quantity of presence is the number of forces deployed. There are three regions where naval forces typically deploy, the Mediterranean Sea (Med), Western Pacific Ocean (WestPac), and Indian Ocean/Arabian Sea (IO). Each of our joint forces has 14 naval groups. We assume a group deploys together to a particular region. With these 14 naval groups, the maximum level of presence which can be maintained each year is 12 months in the Mediterranean, 12 months in the Western Pacific, and 11 months to the Indian Ocean, for a total annual presence of 97 percent (Davis, 1993, p. 25). Presence levels are based on traditional deployment lengths, and maintenance and training cycles during the interdeployment period. Different deployment patterns are possible, but result in a decreased total annual presence percentage. Ignoring the type of naval group deployed, each joint force is equally capable of showing the flag.

The quality of forces present, however, is a necessary concern. Quality is a relative measure, and depends on the threat from adversarial forces. Not all regions or nations have the same level of threat from an aggressor. Likewise, each naval group has different capabilities in countering belligerence. Voss (1991) describes three threat levels, high, medium and low. A high-threat nation possesses sophisticated offensive and defensive air, surface, and subsurface systems. They represent a significant obstruction to the execution of U.S. missions. Medium-threat nations can "impede but not prevent execution of U.S. missions." Low-threat nations possess only small arms or engage in terrorist actions (p. 16). Each threat level is further divided into the likelihood of crises, high, medium and low. Voss argues that a CVBG can operate in all threat and likelihood levels, while a CGTG can operate in anything

less than and including a high threat/low likelihood environment (p. 18). Therefore, we can conclude that quality of presence declines as we move from JF1 to JF3.

B. WARFIGHTING

1. Scenario

We analyze warfighting effectiveness using a stylized scenario over a 21 day period. The scenario is based in Southwest Asia (SWA) because of few bases from which land-based forces can operate and its distance from the CONUS places maximum strain on surging forces into the theater. The analysis focuses on the air campaign prior to the introduction of ground troops.

We assume an aggressor launches a short-notice (1 week) attack, or D-day = C+7. Deployed naval forces surge into the region at 20 knots on C+0. Naval forces in the CONUS deploy on C+2, also at 20 knots. Travel times (Davis, 1993, p. 31) are contained in Table 7. The assumed naval group deployment patterns, and groups available to deploy from the Atlantic Coast (LANT) and Pacific Coast (PAC) are derived from analysis done by Davis (1993), and listed in Table 8. Carrier aircraft used for strike missions are the F/A-18E/F. All others provide strike support, such as fighter escort, airborne early warning, and electronic jamming, but their contribution to the conflict is not quantitatively analyzed. Strike aircraft have a mission capable (MC) rate of 80 percent, and a sortie rate of 2.0 (*Sortie Generation Factors*, 1994).

	Days	Days for Stops	Total Days
Med	7	0	7
WestPac	9	0	9
LANT	17	1	18
PAC	24	2	26

Table 7. Travel time from various regions to SWA at 20 knots. After Davis (1993).

	IO	WestPac	Med	LANT	PAC
JF1	CVBG	CVBG	CVBG	CVBG	CVBG
JF2	CGTG	CVBG	CVBG	CVBG	CVBG
JF3	CGTG	CVBG	CGTG	CGTG	CGTG

Table 8. Naval groups deployed or capable of deploying for scenario.

Assumptions for the bomber force are drawn from Bowie (1993). In the scenario, 75 percent of the B-1B force is used, with the remaining 25 percent reserved for strategic deterrence. In the week before hostilities, one-third of the B-1Bs allocated are moved to an overseas base. All B-2A and B-52H are employed. Bombers based in the CONUS, after completing their mission, recover at the overseas base to a maximum number of 64. The order of precedence for moving bombers overseas is B-1B, B-2A and B-52H. All bombers have a MC rate of 85 percent. Sortie rates for CONUS-based bombers are 0.25, for theater-based bombers 0.5.

Ships salvo all TLAM in two days (Bowie, 1993). The CG-47s and DDG-51s remain in the theater to provide air protection. All DD-963s rearm, which requires a transit to Diego Garcia (4 day transit, 1 day reload, 9 day total turnaround). In order to allow a comparison between TLAM and aircraft, all aircraft carry precision munitions (PGMs). The B-1B carries 24, B-2A 16, and B-52H 12 PGMs respectively (*Conventional Delivery Potential*, 1993). The F/A-18E/F carries 2 PGMs (Labelle, 1994).

Table 9 shows the forces present at D+21. Table 10 displays the scenario timeline.

	CVBG	CGTG	Bombers
JF1	4	0	21
JF2	3	1	138
JF3	1	4	256

Table 9. Forces employed in SWA scenario at D+21.

C-Day	D-Day	Event
0		Warning of hostilities in SWA Deployed naval forces surge to SWA
2		CONUS naval groups deploy B-1Bs move overseas
7	0	Hostilities begin Med naval group arrives Additional bombers move overseas
9	2	WestPac naval group arrives
20	13	LANT naval group arrives
28	21	Scenario ends

Table 10. General scenario timeline.

2. Measures of Effectiveness

Two measures of effectiveness (MOEs) are used, aimpoints hit and sorties flown. Aimpoints hit is a measure of strength, and is used rather than the more traditional tons of ordnance delivered due to the use of PGMs, which make it possible to destroy a target with only one weapon. However, some targets may cover a wide area, such as a power generation station, and therefore several aimpoints within the target area must be hit. Another reason for the use of aimpoints is not all PGMs are of the same tonnage. Twice the tonnage may make a bigger hole, but only one aimpoint will still be destroyed.

Unlike aimpoints, sorties are not a final output, but can increase the flexibility of a force, and are a good measurement of responsiveness and coverage. An aircraft will typically fly a sortie to a single target area, rather than attack several targets widely dispersed. Associated with each sortie is a notional payload, and this MOE is a proxy for responsiveness and dispersal of payload. The sortie measure therefore captures effectiveness in both time and battlespace which is not captured by the aimpoints measure. In essence, aimpoints deals more effectively with the mean of combat, or number of targets destroyed, while sorties gauges the variance, or the uncertainty and dynamic nature, of combat.

With the MOEs defined, we can identify the capabilities of the different components in the joint force. Two types of CVW are used, CVW-1 and CVW-2. CVW-1 is the standard airwing with 36 F/A-18E/F. CVW-2 is an enhanced airwing with 72 F/A-18E/F. With the CVW-2 no changes are made to the joint force structure, except for increasing the number of strike aircraft on each CVN using existing additional aircraft from non-deployed airwings or BAI. Some rearrangement of other aircraft is required on a CVN with CVW-2 attached. This may result in some lose in effectiveness in other, non-strike, missions, such as under-sea warfare, which we do not consider. Assuming no attrition, Table 11 lists the effectiveness of each airwing and bomber squadron.

	Number of a/c	MC Rate	Sortie Rate	Sorties/Day	PGMs	Aimpoints/Day
CVW-1	36	0.8	2.0	58	2	116
CVW-2	72	0.8	2.0	115	2	230
B-1B	14	0.85	0.25 0.5	3 6	24	72 144
B-2A	8	0.85	0.25 0.5	2 3	16	32 48
B-52H	14	0.85	0.25 0.5	3 6	12	36 72

Table 11. Carrier airwing and bomber squadron daily effectiveness with no attrition.

3. Data Output Without Attrition

Without considering attrition to forces employed, we can rather easily calculate the effectiveness of each joint force with respect to the MOEs described. TLAM effectiveness is included in aimpoints hit, but not in sorties flown, because it is a single shot weapon with no reattack capability. Results are listed in Table 12 for a 21 day scenario.

		Total Aimpoints Hit	Total Sorties Flown
JF1	with CVW-1	13,148	4401
	with CVW-2	21,572	8613
JF2	with CVW-1	26,844	3991
	with CVW-2	32,716	6927
JF3	with CVW-1	34,536	2844
	with CVW-2	36,856	4024

Table 12. Joint force effectiveness with no attrition.

A readily apparent result is that as the number of bomber squadrons increases, aimpoints hit increases, which is to be expected with the bombers large payload. Also, doubling the size of a CVW has a significant impact on aimpoints hit, if the data for JF1 alone are compared. Finally, the number of aimpoints hit continuously increases from JF1 to JF3 and with each doubling of the CVW.

The reverse is true for sorties flown. Decreasing the number of CVNs in the joint force decreases sorties flown, due to the higher sortie rate of the CVW. However, sorties flown is not continuously decreasing. In fact, sorties flown with JF1 and CVW-1 nearly equals sorties flown with JF3 and CVW-2.

Comparing the buildup of effectiveness as the forces surge into the theater also yields some insights. Using the assumptions from before, we calculate daily effectiveness and cumulative effectiveness for each component. Figure 2 shows daily aimpoints, Figure 3 cumulative aimpoints, Figure 4 daily sorties, and Figure 5 cumulative sorties.

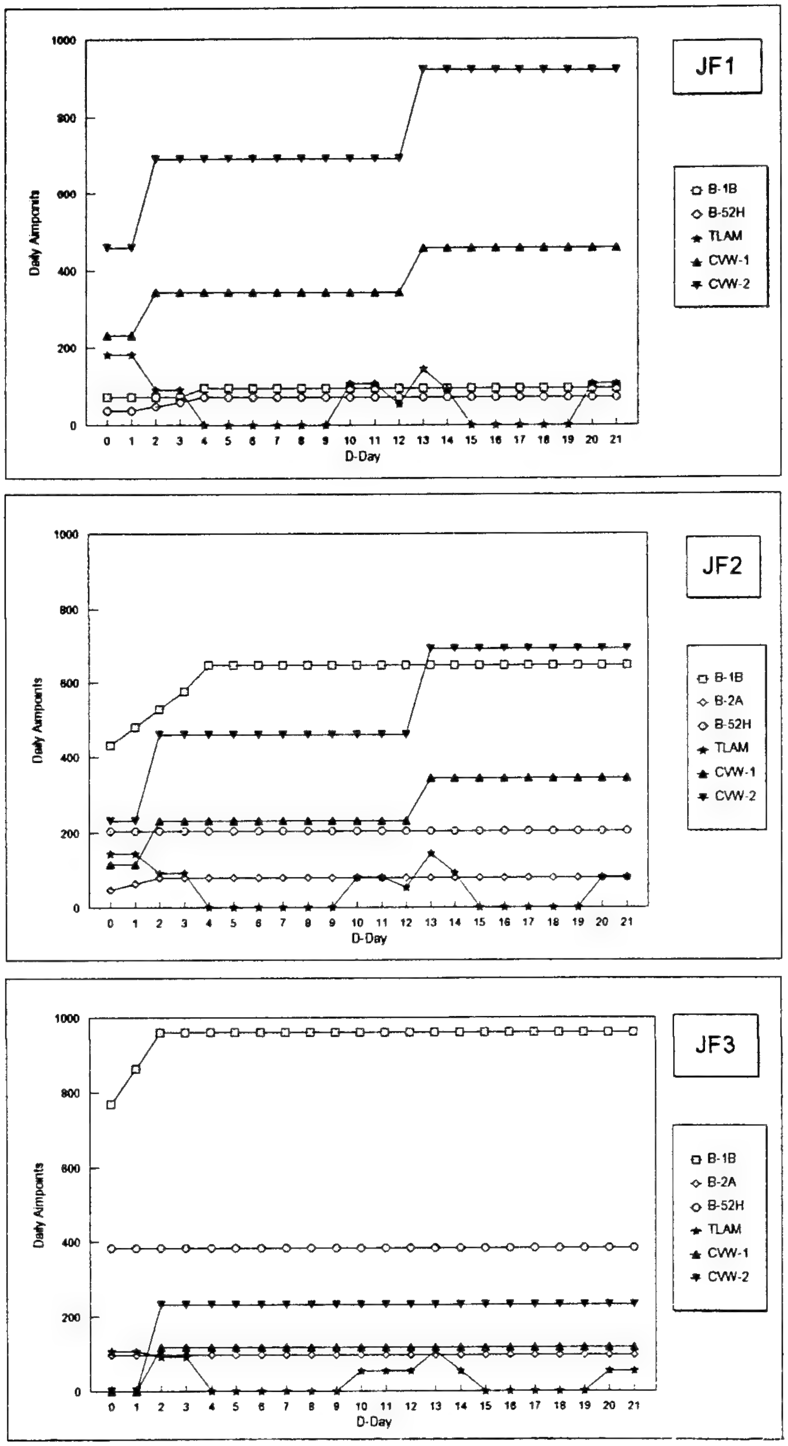


Figure 2. Daily aimpoints, no attrition.

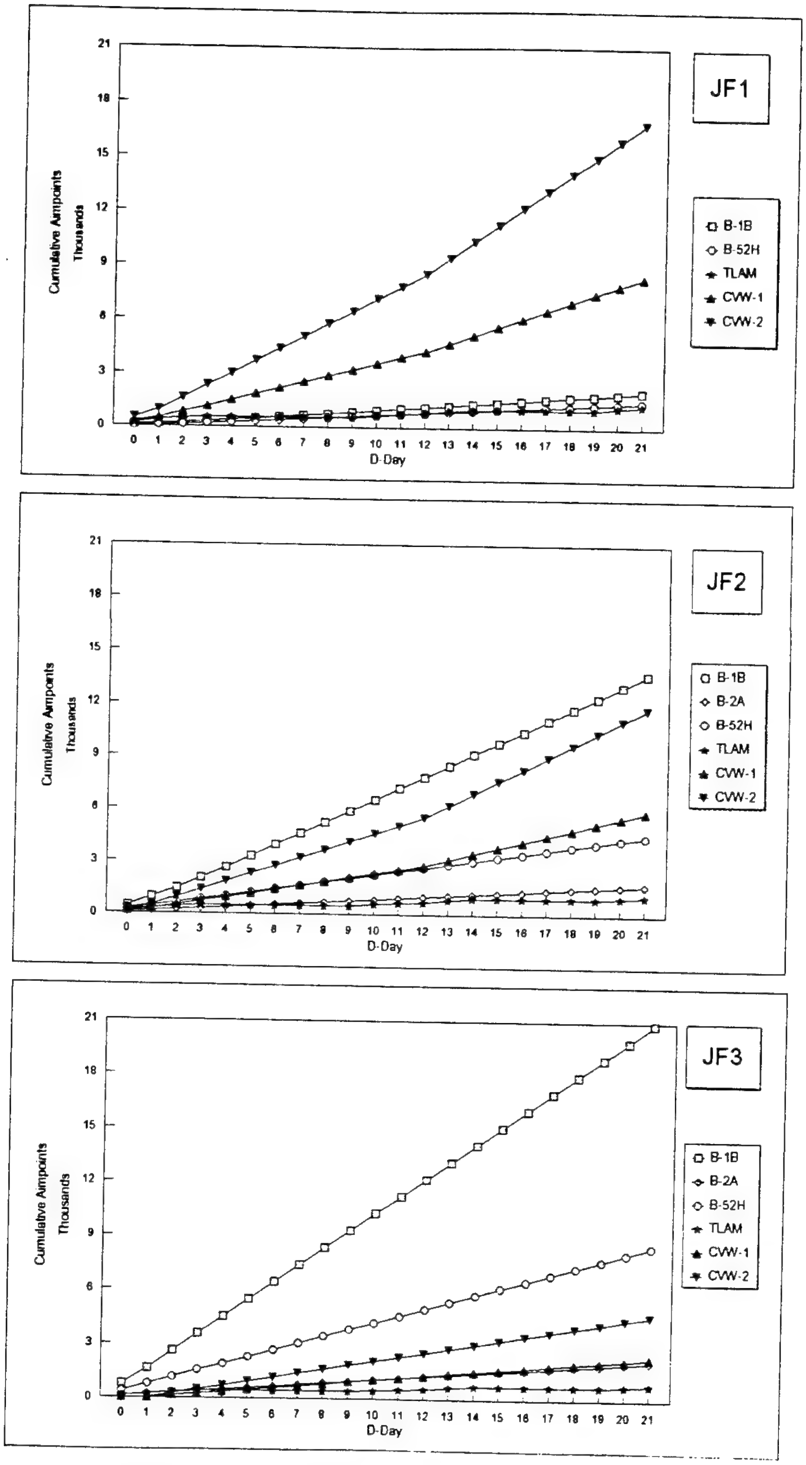


Figure 3. Cumulative aimpoints, no attrition.

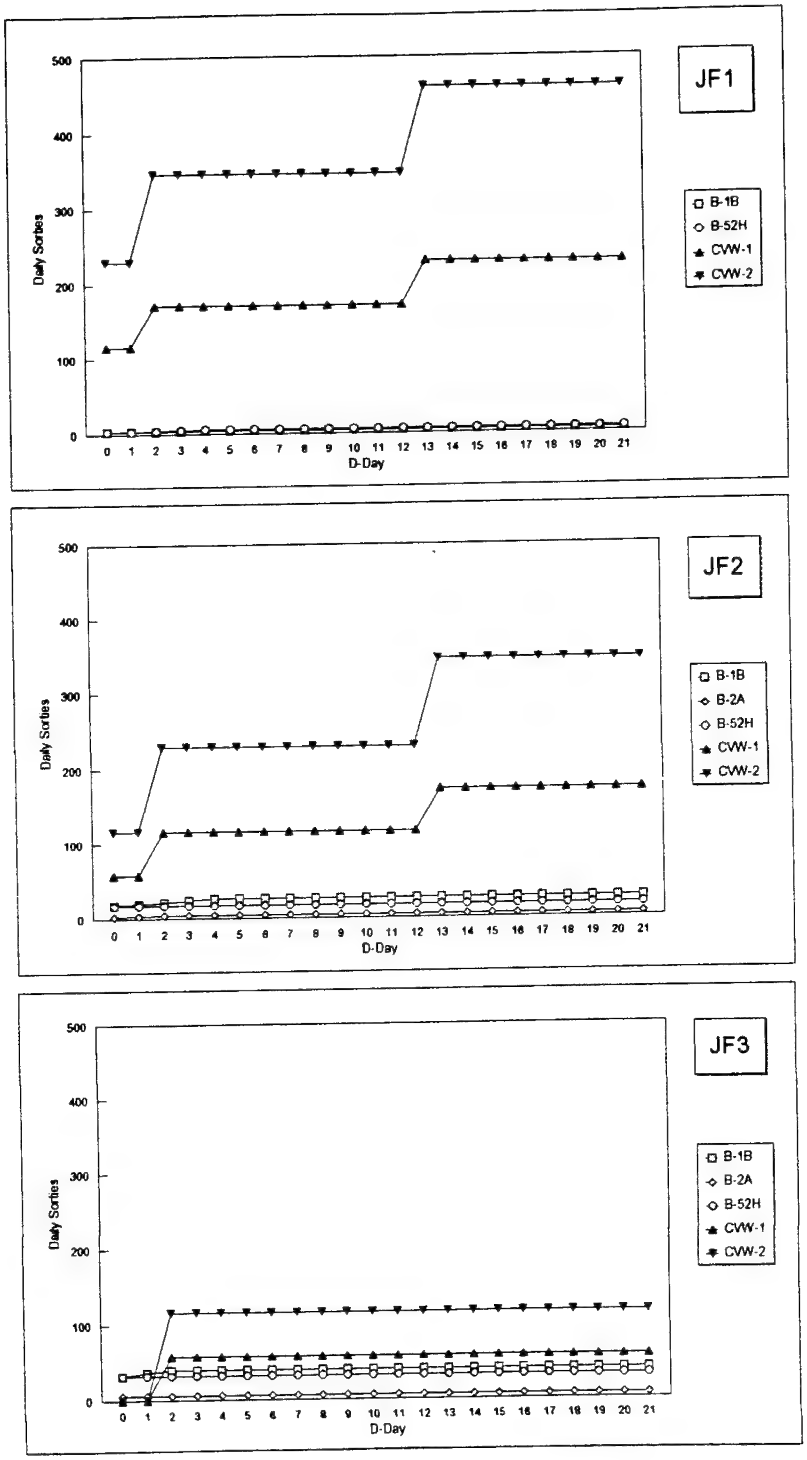


Figure 4. Daily sorties, no attrition.

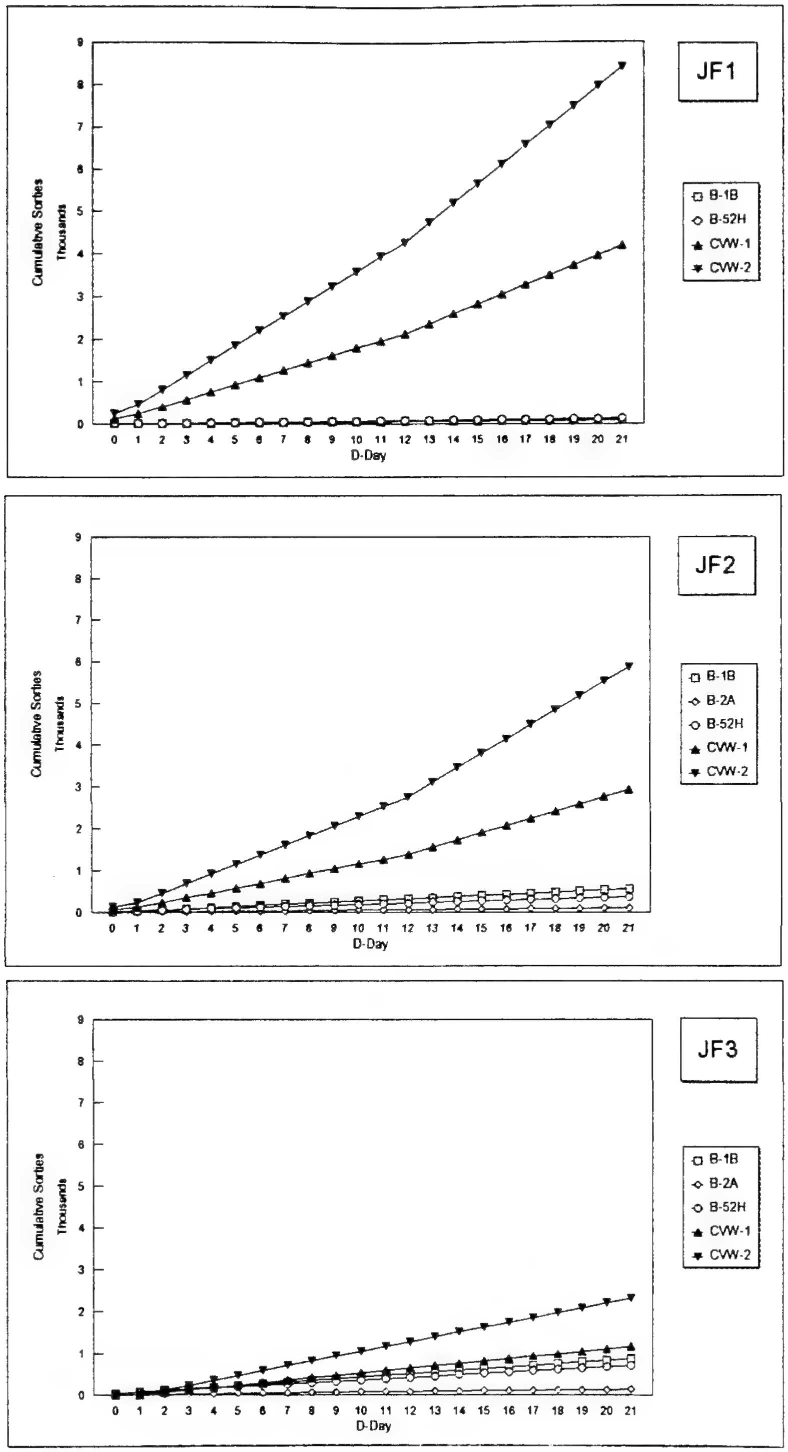


Figure 5. Cumulative sorties, no attrition.

In the figures, CVW-1 and CVW-2 both appear in order to allow comparisons to be made. However, each joint force structure has either one or the other, but not both. Therefore, when computing totals for each MOE, one type of CVW must be eliminated.

Figure 2 clearly shows that bombers quickly reach their maximum potential within the first few days of the conflict. On the naval side, a significant jump in effectiveness occurs with the arrival of a CVN, especially when carrying a CVW-2. Additionally, the daily delivery from four CVW-2s in JF1 after D+13 nearly equals the daily delivery from the B-1Bs in JF3. The B-2A and TLAM both appear to offer little to the campaign in terms of aimpoints alone. However, they most certainly would be assigned the most difficult targets, allowing the other components to more efficiently attack less heavily defended targets. However, quantifying this synergy is beyond the scope of this work. The most notable result from Figure 3 is the rapid buildup of cumulative aimpoints from the B-1Bs in JF3. The JF1 CVW-2 component also shows a significant, although somewhat less, cumulative output. We can conclude from Figures 2 and 3 that a bomber force can attack significantly more aimpoints than a force more reliant upon naval aircraft.

Figures 4 and 5, however, clearly show that naval aircraft are more efficient in producing sorties, both daily and cumulatively. In JF3, the single CVW-2 generates more sorties per day than the entire bomber force combined.

4. Data Output With Attrition

a. Attrition Assumptions

No military force can expect to engage an aggressor without suffering some attrition. Some additional assumptions are needed for this. Bombers lost are replaced from the CONUS inventory, therefore maintaining the maximum force deployed overseas. Attrition loses to naval aircraft, regardless of type of airwing, are replaced at the rate of one standard airwing, CVW-1, per week. If less than one airwing is lost, then only the number of aircraft lost is replaced. Attrition to strike-support aircraft is not calculated. TLAM also suffer loses. Finally, there is no significant threat to naval surface forces. All other assumptions hold.

We calculate aircraft attrition parametrically with rates of 0.02 and 0.04 per sortie. The rates were chosen to obtain a spread of data, with .04 being a plausible upper

limit. The argument can be made that not all aircraft, and certainly not the B-2A, will suffer the same attrition loses. Also, attrition rates should be expected to differ by target attacked and length of campaign. However, the goal is to provide comparisons between joint forces, not to predict actual campaign outcome.

b. Attrition Equation

Schwartz (1988) provides the attrition equation used. The expected number of successful sorties, S, is given by

$$S = \frac{A(1 - p)}{p}[1 - (1 - p)^R]$$

$$\begin{aligned} \text{where: } A &= \text{number of aircraft} \\ p &= \text{attrition rate per sortie} \\ R &= \text{sorties flown.} \end{aligned} \qquad (4)$$

The derivation follows from the geometric probability distribution. The probability an aircraft flies k successful sorties is $p(1-p)^k$. Summing over all values of k from 1 to R and then differentiating yields Equation 4 (Schwartz, pp. 3-4).

c. Data Output

Using equation 4, joint force effectiveness is presented in Table 13 for two percent attrition, and in Table 14 for four percent.

		Total Aimpoints Hit	Total Sorties Flown
JF1	with CVW-1	11,719	3978
	with CVW-2	18,619	7534
JF2	with CVW-1	24,688	3682
	with CVW-2	29,792	6312
JF3	with CVW-1	32,466	2688
	with CVW-2	34,522	3748

Table 13. Joint force effectiveness with 2 percent attrition.

		Total Aimpoints Hit	Total Sorties Flown
JF1	with CVW-1	10,291	3555
	with CVW-2	14,463	5773
JF2	with CVW-1	22,585	3403
	with CVW-2	26,235	5343
JF3	with CVW-1	30,357	2543
	with CVW-2	32,107	3473

Table 14. Joint force effectiveness with 4 percent attrition.

The results are similar to those obtained with zero attrition, aimpoints hit consistently increases as the joint force structure changes from CVWs to bombers, and sorties decreases when comparing the same type of CVW.

As before, examining force effectiveness buildup yields some insights. Figures 6 through 9 present results for two percent attrition, Figures 10 through 13 show results for four percent.

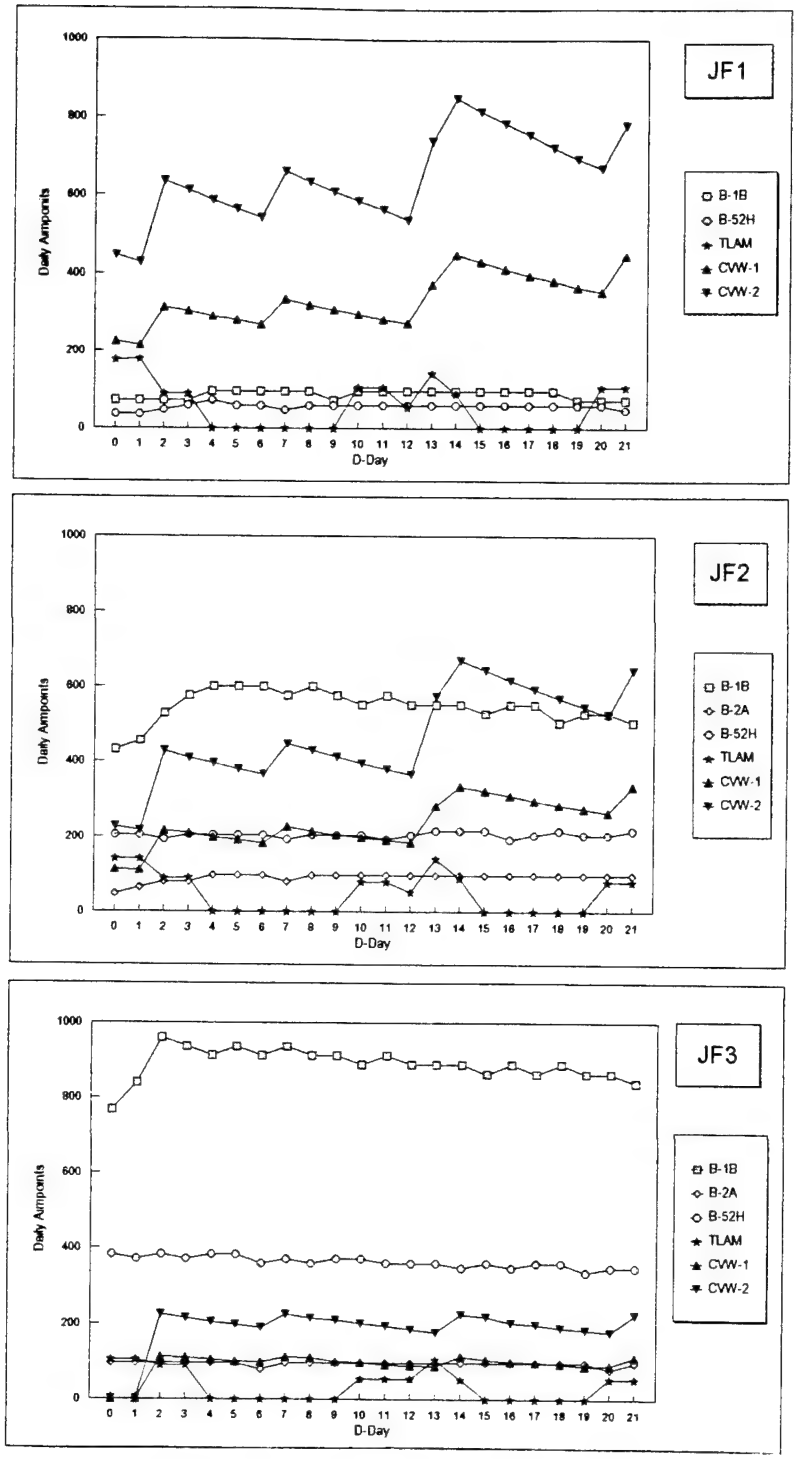


Figure 6. Daily aimpoints, 2 percent attrition.

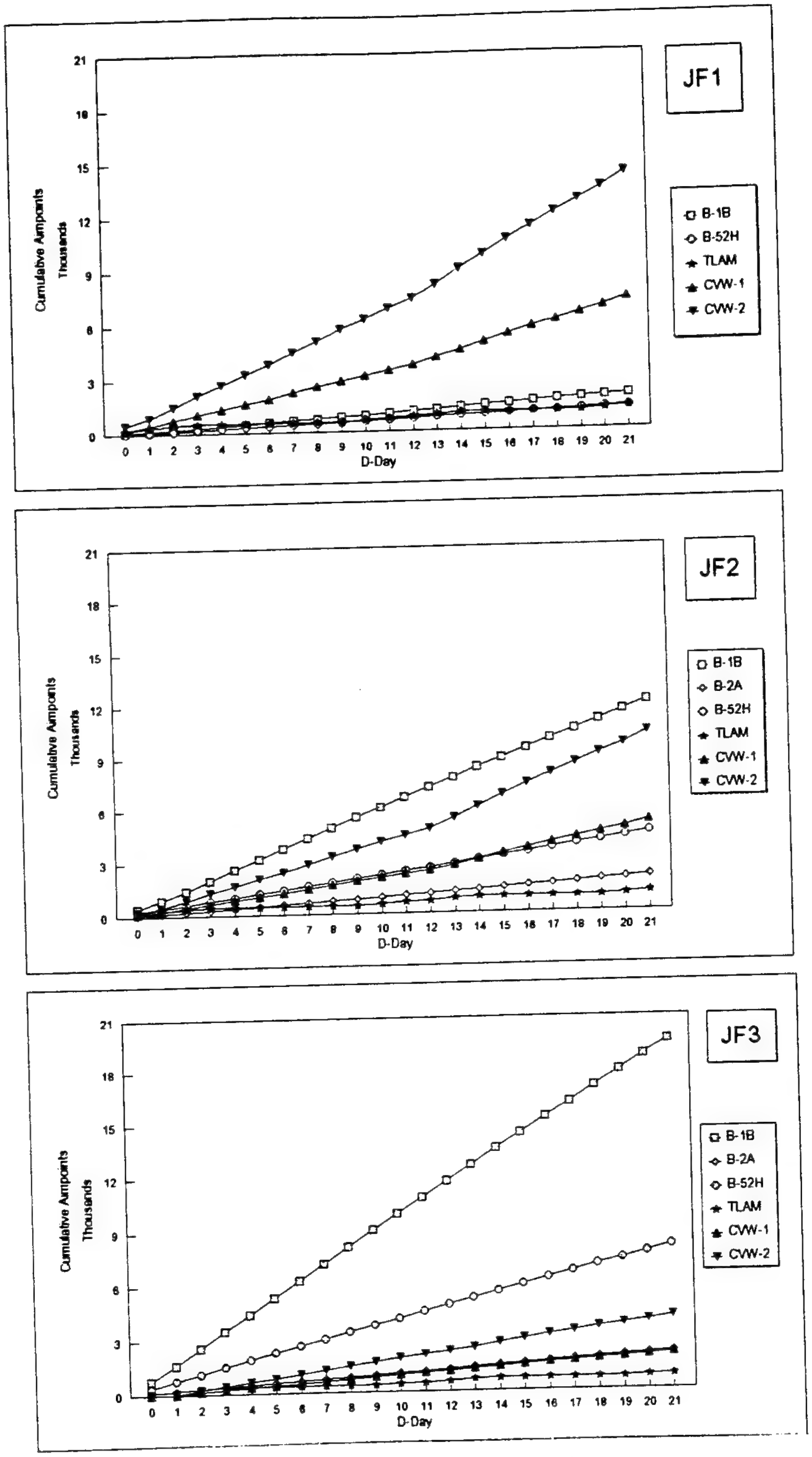


Figure 7. Cumulative aimpoints, 2 percent attrition.

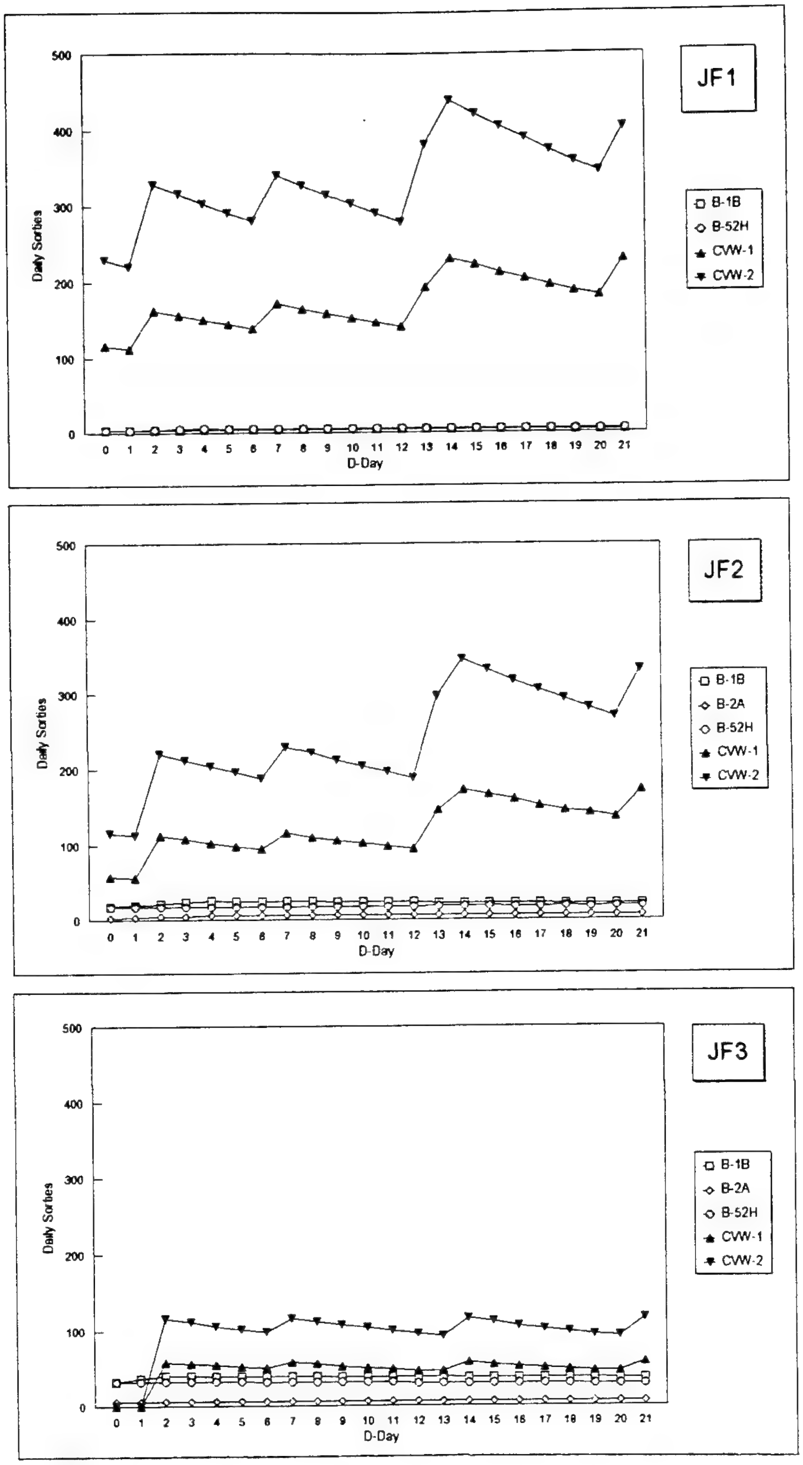


Figure 8. Daily sorties, 2 percent attrition.

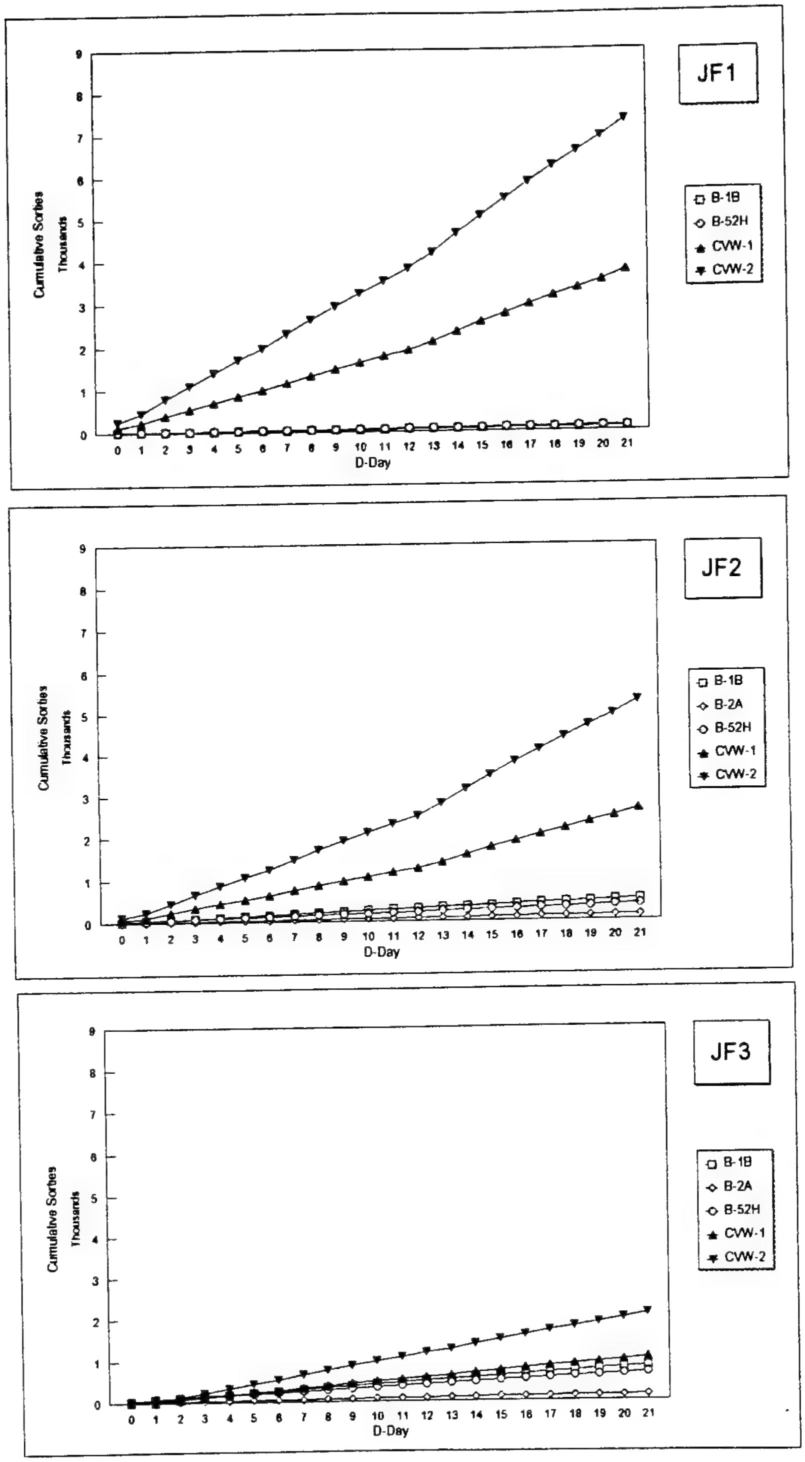


Figure 9. Cumulative sorties, 2 percent attrition.

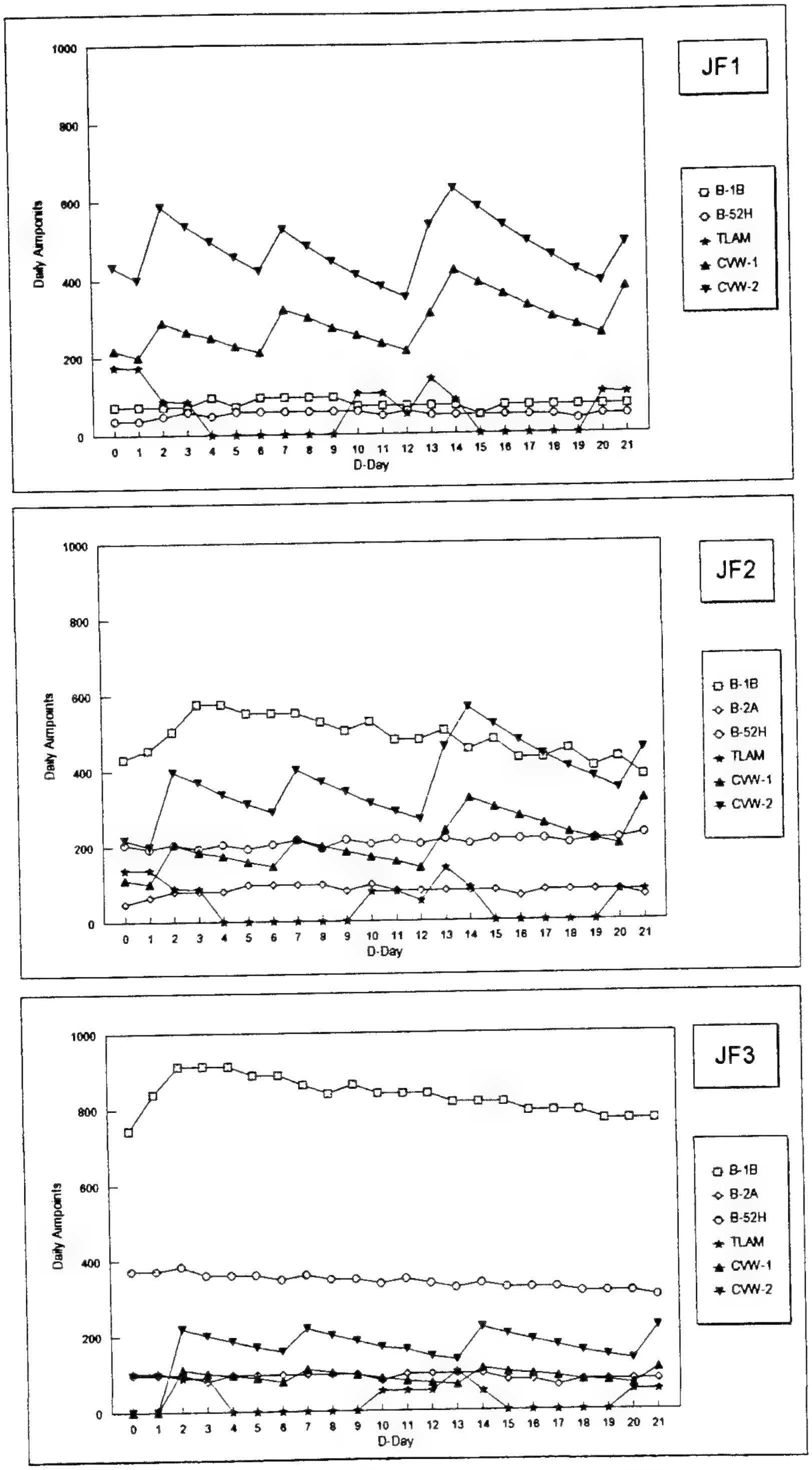


Figure 10. Daily aimpoints, 4 percent attrition.

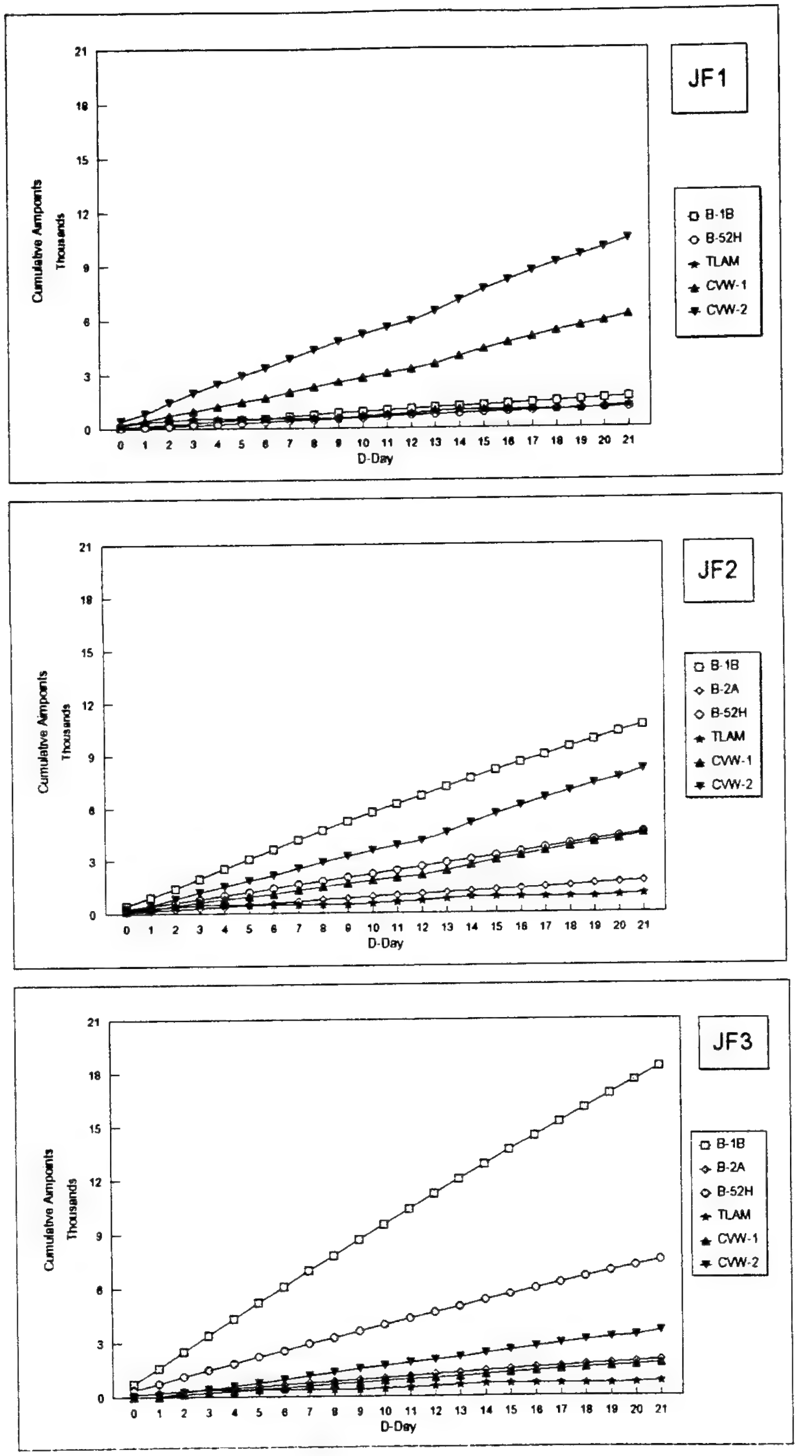
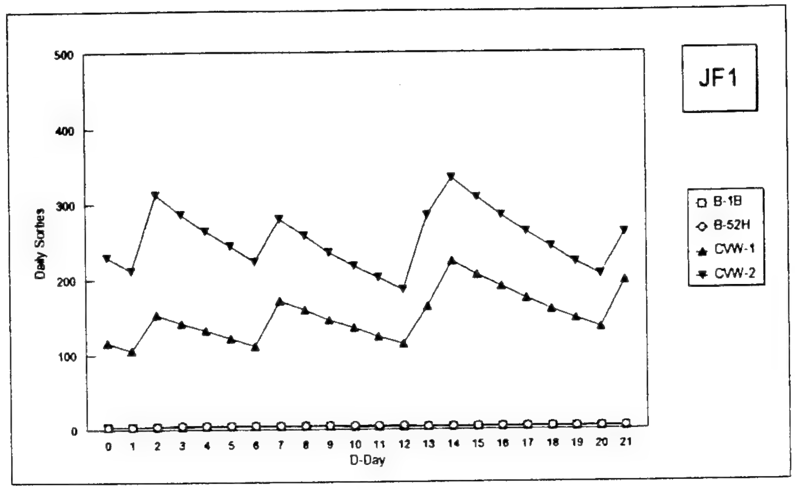
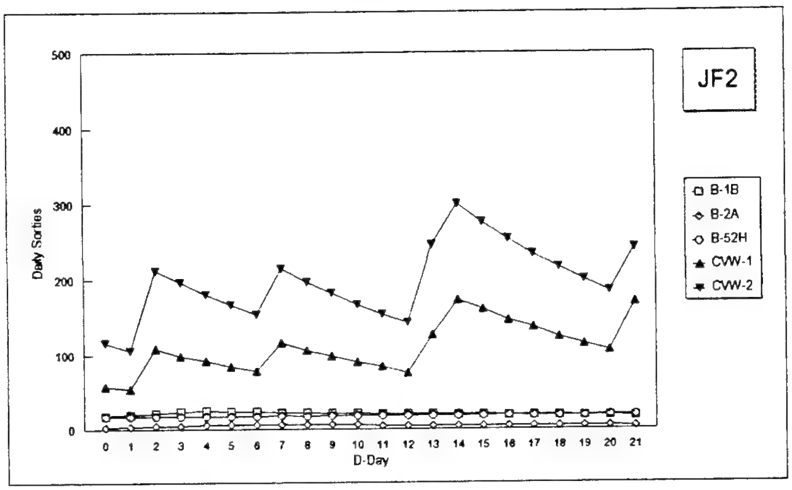


Figure 11. Cumulative aimpoints, 4 percent attrition.





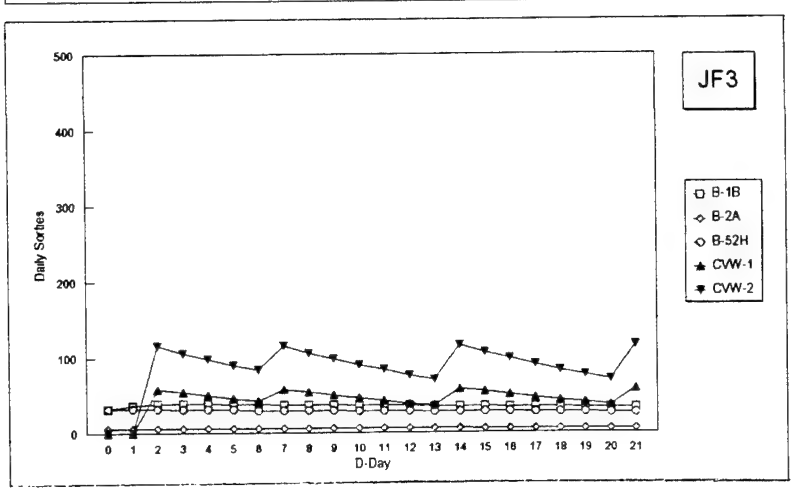


Figure 12. Daily sorties, 4 percent attrition.

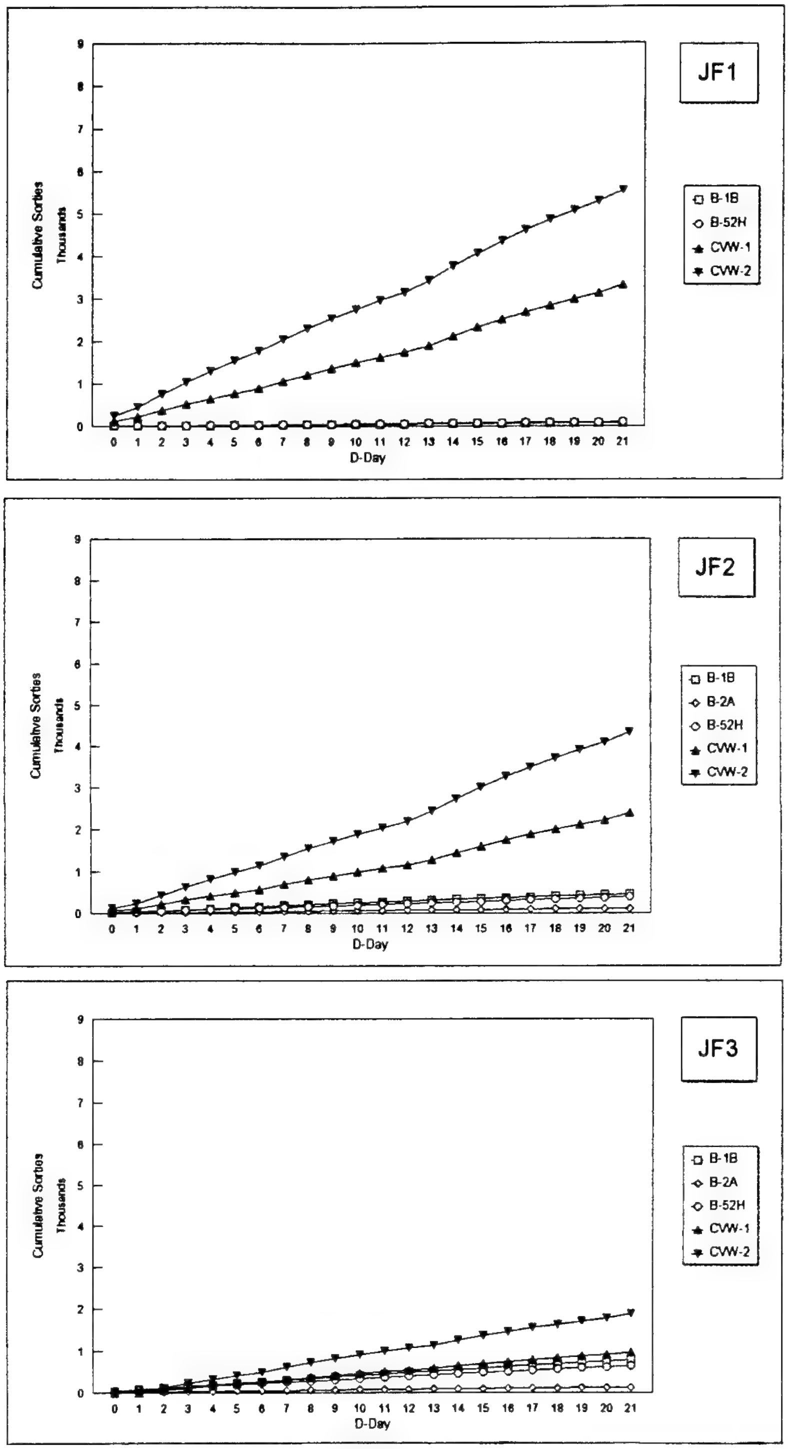


Figure 13. Cumulative sorties, 4 percent attrition.

The Figures reveal that with attrition considerations, bombers have an even larger advantage in aimpoints. Low sortie rates prevent bomber inventories from rapidly depleting. Carrier aircraft continue to dominate sorties flown, and their ability to replenish loses is a great advantage. However, loses begin outpacing the rate of replenishment at four percent attrition when three or more CVWs are in operation.

d. Measures of Loss

We have analyzed the measures of effectiveness for the joint forces, both with and without attrition. The conclusions in both conditions are generally in agreement. However, attrition results in more than a loss in immediate effectiveness. There is also a loss of equipment and people which has long-term implications. Large losses can have a political dimension, as the national will begins to erode with increasing attrition. Two measures of loss (MOL) are used; the dollar loss of aircraft, measured in annualized procurement cost, and the number of crew at risk. Crew size (Nicholas, *U.S. Military Aircraft*, 1977-1994) for an F/A-18E/F, B-1B, B-2A and B-52H is 1, 4, 2, and 6 respectively. Table 15 summarizes the MOLs.

Attrition Rate		0.02			0.04		
		Aircraft Lost	Cost	Crew	Aircraft Lost	Cost	Crew
JF1	with CVW-1	79	$ 253	95	138	$ 436	167
	with CVW-2	149	451	165	225	681	254
JF2	with CVW-1	73	544	146	124	976	276
	with CVW-2	125	691	198	210	1191	352
JF3	with CVW-1	55	595	179	101	1072	332
	with CVW-2	76	655	200	137	1173	368

Table 15. Aircraft lost, annualized procurement cost in millions of FY 95 dollars, and number of crew at risk.

The number of aircraft lost decreases because of a greater employment of bombers with fewer sorties. However, each bomber costs significantly more and carries greater crew size, therefore both of those measures increase.

5. Opportunity Costs

Associated with each joint force is an opportunity cost of capability foregone. These costs are not as easily measured as the MOLs above. However, they are an important consideration when analyzing force structure and identifying synergistic relationships. We examine opportunity costs much in the same manner as we analyzed force effectiveness, beginning with deterrence.

Even when engaged in a regional conflict, deterring additional conflicts is still a significant role of the nation's military, and more specifically a role of naval forces. Although deployed forces and forces surged from the CONUS are employed in ending the conflict, additional forces must deploy, also from the CONUS, to reconstitute presence. As before, these presence forces must be credible in the psyche of other aggressors. This second aggressor may recognize the U.S. as entrenched in the first conflict, and therefore unwilling, or unable, to respond to a second. Although a CGTG packs an significant punch, a CVBG has even more potential and would be the preferred deterrent force if the circumstances dictate. Davis (1993) analyzed the surge capabilities of several CVN force levels (p. 32), summarized in Table 16.

	Number of carriers deployed or capable of surging at (months)				
CVNs	0	1	2	3	6
14	6	8	9	9	12
10	4	5	8	8	10
6	1	1	4	4	6

Table 16. Number of CVNs capable of surging by month and force level. From Davis (1993).

A force level of 14 CVNs (JF1) has a clear edge in reconstituting presence. This force is capable of providing four CVBGs to a conflict, and still maintain presence in two other regions with a CVBG. JF2, with 10 CVBGs, could also reconstitute a credible presence. JF3, however, has only one CVBG available, and it is deployed. It requires another two months before additional CVNs can be deployed. An aggressor could potentially view this as a sign of weakness. Table 17 shows the number of CVBGs employed in the conflict (assuming only those arriving before D+21 are used), the forces deployed to reconstitute presence, and the number of CVNs capable of deploying in the future.

	CVBGs	Presence Forces		Number of CVNs to surge at		
	Employed	Med	WestPac	1 month	2 months	6 months
JF1	4	CVBG	CVBG	2	1	3
JF2	3	CGTG	CVBG	1	3	2
JF3	1	CGTG	CGTG	0	3	2

Table 17. Number of CVBGs employed in the scenario at D+21, forces deployed to reconstitute presence, and number of CVNs capable of surging in the future.

Forces available to swing from the first conflict to a second is another important consideration. Consideration must be given to national security objectives in each region when deciding which conflict takes precedence, so we limit our discussion to general terms. As before, response time is a factor. Bombers can respond rapidly, possibly even using the same overseas base for both clashes. Naval groups may require a week or more to arrive, depending on the presence posture. Regardless of the type of naval group providing presence, surface combatants can provide TLAM. JF1 can provide a significant CVN level to each conflict, however the bomber level of effort is already meager, and would unlikely be split between two confrontations. A carrier force would most likely have to fight one conflict alone, providing only a delaying effort. However, by using CVW-2 its effectiveness, by both measures, increases significantly. The second joint force, JF2, is more balanced. Several CVNs could be furnished to each conflict, and the bomber forces could also be split as

needed. JF3 poses a different obstacle. Bombers available to divide is not an issue. However, having only one CVN accessible clearly represents a predicament, due its role in supplying strike support, which leads us to our final opportunity cost.

With exception for the B-2A in some circumstances, bombers require some level of strike support, such as fighter escort, airborne early warning, or electronic jamming. Without land-based tactical aircraft, this responsibility falls upon the CVN. Undoubtedly, JF1 and JF2 can fulfill the role, but it is questionable that JF3 would be up to the task. Even more dangerously, the first two days of the scenario have the bombers fighting unsupported. For this joint force structure, it may be wise to augment support aircraft instead of employing CVW-2. However, a second conflict exacerbates the problem.

6. Tanker Requirements

Long-legged, bombers flying missions from the CONUS require aerial tanking, and we make a rough estimate of those requirements. Nicholas (*U.S. Military Aircraft*, 1977-1994) estimates the fuel capacity and combat range of each bomber, and the fuel capacity of the KC-10A aerial tanker, listed in Table 18.

	Fuel (Klbs)	Range (nm)	Fuel Efficiency (lbs/nm)
B-1B	193.4	7500	25.79
B-2A	160.0	7300	21.92
B-52H	312.8	7500	41.71
KC-10A	356.1	n/a	n/a

Table 18. Aircraft fuel capacities, combat ranges, and fuel efficiencies. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Roundtrip distances from an overseas base to SWA is approximately 6,000 nm, from the CONUS is 12,000 nm (Perin, 1991, p. 40). All bombers can complete a mission unrefueled from the overseas base, so we can exclude that from our analysis. We then need to estimate requirements for aircraft flying CONUS-to-CONUS, and CONUS-to-overseas. The B-1B is used as the example. First, the distance beyond combat range for CONUS-to-

CONUS is determined, which is 4500 nm, and then multiplied by fuel efficiency for additional pounds of fuel required, or 116,055 lbs. Divided by the capacity of the tanker gives the result that a B-1B will require one-third of a KC-10A's capacity to complete a CONUS-to-CONUS mission. For a CONUS-to-overseas, the mission distance is 9000 nm, which yields a requirement of one-tenth of a KC-10A. Requirements for all bombers is listed in Table 19.

	CONUS-to-CONUS	CONUS-to-overseas
B-1B	.33	.11
B-2A	.29	.10
B-52H	.53	.18

Table 19. Bomber aerial tanker requirements in KC-10A equivalents.

If we assume that bombers prefer to make only one refueling, then the limiting factor is the B-52H flying CONUS-to-CONUS, and will require one KC-10A for each B-52H. Any other combination of bomber and mission can utilize the excess capacity. Table 20 shows the maximum daily sorties for all bombers and mission types.

		JF1	JF2	JF3
B-1B	CONUS-to-CONUS	0	0	9
	CONUS-to-overseas	2	9	16
B-2A	CONUS-to-CONUS	n/a	1	7
	CONUS-to-overseas	n/a	4	0
B-52H	CONUS-to-CONUS	0	18	33
	CONUS-to-overseas	3	0	0

Table 20. Maximum daily sorties by bomber and mission type.

The daily sortie requirement of KC-10As for JF1, JF2, and JF3 is 1, 18, and 33 respectively. These requirements do not account for refueling of naval aircraft and are rough estimates only.

C. TOTAL FORCE EFFECTIVENESS

The conceptual model introduced in Chapter II provides the framework for determining total effectiveness of each joint force. To assist in the comparison, the results are summarized in Table 21.

		JF1	JF2	JF3
	Total CVNs	14	10	6
	Total bombers	28	184	340
Presence	Quantity		Equal	
	Quality	Greatest	-------------->	Least
Warfighting	Aimpoints	Least	<--------------	Greatest
	Sorties	Greatest	-------------->	Least
Opportunity Costs	Fulfill presence	Greatest	-------------->	Least
	Fight two wars	Few bombers	Best	Few CVNs
	Strike Support	Greatest	-------------->	Least

Table 21. Summarization of joint force effectiveness.

None of the joint forces immediately emerges as the best choice. Some loss of deterrence occurs from lower quality of presence as the joint force structure moves from JF1 to JF3. However, a critical consideration is whether any gain in warfighting effectiveness contributes sufficiently to improve deterrence. This depends on which warfighting MOE holds more importance. We will simply assume that deterrence is maintained among all three joint forces. However, opportunity costs play an enormous role. Although we have concluded that deterrence is maintained, this is only true for a single conflict. A potential aggressor may choose to act if the U.S. were already engaged in another struggle. With this argument, JF1, although it reconstitutes presence effectively, lacks strength to fight in two regions. Similarly, JF3, although the most capable at destroying the enemy, is vulnerable without strike support. Both forces lack the necessary synergy to operate effectively in all situations.

Only JF2 appears to fully capture the synergy required. The force structure is balanced, such that the components are capable of supporting each other across all levels of deterrence and warfighting. This does not suggest that this force structure is the best out of all possible candidates, but it is the best choice of the three joint forces analyzed for the defense expenditures committed.

V. CONCLUSIONS

A. SUMMARY OF RESULTS

The military has two primary roles, deterrence of aggression and winning wars when deterrence fails. Deterrence significantly depends on forces visibly present in a region, notably naval forces. Winning wars requires a military that can respond rapidly and project sufficient strength against an aggressor. With a budget constraint, the nation cannot build a military structure that maximizes the effectiveness of each role. Instead, some reduction in effectiveness with respect to each role must be accepted, while relying on synergistic effects among force components that increase total force effectiveness.

Synergy among military forces exists on two levels, strategic and tactical. Strategically, deployed naval forces engaged in presence represent all military forces. Warfighting effectiveness acts as a force multiplier in improving deterrence effectiveness. Tactical synergy comes in many flavors. Deployed forces form the leading edge of rapid response. Military components, in their operating methods, increase warfighting effectiveness beyond what each individual component could do alone. In force structure decisions, simply making tradeoffs of weapons systems is not sufficient. The military must also capture the synergistic effects.

We analyzed the changes in deterrence and warfighting effectiveness for the joint conventional strike force, the components of which are aircraft carriers and their airwings, naval combatants with Tomahawk missiles, and long-range bombers. The components were assembled into three equal cost joint forces.

Deterrence effectiveness decreases as the number of carriers declines. However, warfighting effectiveness may improve as more bombers are acquired, offsetting somewhat the loss in deterrence. In considering warfighting effectiveness, carrier aircraft were shown to be far more effective in producing sorties, a proxy for the responsiveness and coverage of targets by strike assets, while bombers hold the edge in number of aimpoints hit. But deciding on which force structure to advocate requires more than a tradeoff between deterrence and warfighting. The effects on synergy must also be considered.

A joint force structure with an emphasis on carriers has the best deterrence. But its warfighting effectiveness declines because sufficient bombers do not exist to destroy a large number of targets. Expecting primarily carrier aircraft to accomplish this mission may expose them to significant attrition risks. Placing a heavy reliance on bombers results in some loss in deterrence, but a significant number of targets can be hit quickly. However, the bombers also may be exposed to attrition risks due to the reduction in strike support provided by carriers. Therefore, total effectiveness is likely to be maximized with a balanced force.

The continuing argument over carriers versus bombers, therefore, is unproductive. The nation's military needs both and should focus its efforts at improving joint operational effectiveness. Fryer (1995) provides an excellent description of the immense potential of joint operations which were demonstrated in a recent exercise called Kansas Global Lancer. Two B-1Bs launched from the U.S. to the island of Corsica on a bombing exercise. Naval aircraft provided suppression and fighter escort for the mission. More exercises such as this are undoubtedly necessary.

With a shrinking defense budget, force planners need to overcome the urge to compare weapons systems. Emphasis needs to be placed on the tradeoffs in joint capabilities, and how total effectiveness can be increased.

B. FUTURE STUDY QUESTIONS

1. What is the optimal mix of forces for strike warfare? The contribution of all joint strike assets, land and sea-based aircraft, bombers and TLAM, needs to be analyzed. Accomplishing this will require a serious examination of the synergy among the forces, including strike support, and a determination of the mix that will maximize effectiveness.

2. Does presence really deter war? The relationship among presence, warfighting and foreign policy must be analyzed to determine the relative emphasis that should be given to each.

APPENDIX. COST CATEGORIES

This appendix describes the hierarchy of cost categories. Some discussion of O&S cost components is presented, along with an alternative O&S model for comparison with VAMOSC data. Finally, the cost breakdown for all joint force components is contained in Tables 23 through 39.

Life Cycle Costs (LCC) are the total costs associated with a system over its lifetime. It is at the peak of the cost hierarchy, depicted in Figure 14.

LCC
(Operating & Support, Industrial Facilities, Common Support Equipment)
+
PROGRAM COSTS
(Research, Development, Test & Evaluation, Military Construction, Ammunition)
+
PROCUREMENT COSTS
(Initial Spares, Product Improvement)
+
WEAPONS SYSTEM COSTS
(Data, Ground Support Equipment, Training, Advance Procurement, Peculiar Support)
+
FLYAWAY COST
(Non-Recurring, Project Management, Test & Evaluation)
+
HARDWARE RECURRING COST
(Government Furnished Equipment, Engineering Changes)
+
MANUFACTURING DESIGN-TO-COST
(Initial Design-To-Cost)

Figure 14. Cost hierarchy structure. From Nicholas (*U.S. Military Aircraft*, 1977-1994)

This cost structure applies to all military systems, although for ships flyaway cost becomes sailaway cost. Cost allocation becomes more difficult to determine as we move towards the top of the structure. Different systems begin using the same infrastructure, such as basing different aircraft types at the same airfield, or the homeporting of ships. Because of

this, cost estimates vary significantly depending on the method of allocation. A good example is the treatment of O&S costs.

The VAMOSC system was established to identify and report historical O&S costs, and as a tool for predicting future weapon system O&S costs. The general cost elements include personnel, consumables (fuel, ammunition), intermediate maintenance, depot maintenance, sustaining investment (spares, modification kits), and indirect support (*Generic Cost Estimating Guide*, 1984). The last element is not uniformly applied among the services. Included in indirect support is base operating and support (BOS) costs. The Air Force this category while the Navy does not, partially due to the difficulty in allocating costs when ships or aircraft are deployed.

An alternative method of estimating O&S is with the Quick Cost Model used by the Congressional Budget Office (CBO) (Vassar, 1989). The model costs the changes in Primary Defense Forces, e.g. aircraft or ships (p. 3). It has a hierarchical structure which links the primary forces to 12 categories of support elements. Changes in a category causes percentage changes in all subordinate categories based upon regression analysis conducted by CBO (pp. 8-10). An advantage of the Quick Cost Model is its applicability to all services. For comparison Table 22 lists O&S estimates from VAMOSC and Quick Cost for a CVBG and the bomber squadrons. The VAMOSC data does not include BOS, while Quick Cost does.

	VAMOSC	Quick Cost
CVBG	$ 629.217	$ 807.022
B-1B	95.878	148.928
B-2A	132.500	152.384
B-52H	96.561	129.025

Table 22. Comparison of O&S estimates from VAMOSC and Quick Cost.

Aircraft	B1-B		TAI	94	PAA/Squadron	14
Service Life	20		Squadrons	6		

Year	Qty	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1981		219.000	347.390		0.000	
1982	1	471.000	707.711	1612.000	2399.343	
1983	7	753.500	1092.222	4033.500	5745.125	
1984	10	737.200	1030.608	6124.500	8440.071	
1985	34	462.500	627.363	7480.700	10000.350	
1986	48	248.400	328.109	4799.400	6215.208	
1987		115.700	148.083		0.000	
1988		366.800	452.416		0.000	
1989		221.600	262.374		0.000	
Totals	100		4996.276		32800.097	
Average Cost					328.001	
Annualized Cost/Aircraft					16.400	
Annualized Cost/Squadron					256.934	95.878
Total Annualized Cost/Squadron	352.812					

Table 23. B-1B cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	B-2A		TAI	20	PAA/Squadron	8
Service Life	20		Squadrons	2		
Year	Qty	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1988	3	13200.000	16281.062	4100.000	4937.385	
1989	3	2176.500	2576.970	3036.900	3529.930	
1990	2	1859.700	2117.767	2302.400	2592.482	
1991	2	1715.700	1885.942	2348.400	2573.975	
1992	1	1522.300	1638.131	2298.200	2459.367	
1993	4	1189.300	1243.796	2642.000	2762.791	
1994		785.800	803.481	756.800	773.752	
1995		408.500	408.500	386.700	386.700	
Total	15		26955.648		20016.384	
Average Cost					1334.426	
Annualized Cost/Aircraft					66.721	
Annualized Cost/Squadron					667.213	132.500
Total Annualized Cost/Squadron	799.713					

Table 24. B-2A cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	B-52H		TAI	94	PAA/Squadron	14
Service Life	20		Squadrons	6		

Aircraft	Average Flyaway $	Average Procurement$	Ratio		
B-2A	901.000	1345.867	1.494		
B-1B	207.000	240.458	1.162		
EA-6B	23.500	36.182	1.540		
E-2C	35.300	44.412	1.258		
F-14D	31.400	72.948	2.323		
F/A-18A-D	21.200	31.873	1.503		Average Ratio
S-3	11.700	14.400	1.231		1.502
B-52H	54.283	81.506			
Annualized Cost/Aircraft		4.075			
				O&S	
Annualized Cost/Squadron		63.847		96.561	
Total Annualized Cost/Squadron	160.408				

Table 25. B-52H cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	F-14D		Aircraft/Wing	14	
Service Life	18		TAI/Wing	20.73	

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1982		5.300	7.964		0.000	
1983		6.500	9.422		0.000	
1984		40.600	56.759		0.000	
1985		276.700	375.333		0.000	
1986		347.900	459.537		0.000	
1987		278.700	356.704	92.500	115.684	
1988	7	168.000	207.214	818.800	986.032	
1989	12	152.600	180.678	951.300	1105.740	
1990	24	117.800	134.147	1530.500	1723.330	
1991	12	119.800	131.687	1115.700	1222.868	
1992		115.100	123.858	185.100	198.081	
1993		120.100	125.603	152.000	158.949	
1994		70.900	72.495		0.000	
1995		171.700	171.700		0.000	
Total	55		2413.100		5510.685	
Average Cost					100.194	
Annualized Cost/Aircraft					5.566	1.798
Annualized Cost/Wing					115.383	37.270
Total Annualized Cost/Wing	152.654					

Table 26. F-14D cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	F/A-18E-F	Aircraft/Wing	36
Service Life	15	TAI/Wing	53.30

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1975		20.000	52.598		0.000	
1976		131.200	320.861		0.000	
1977		341.100	766.538		0.000	
1978		625.100	1296.743	34.200	70.596	
1979	9	498.600	944.283	539.900	1011.719	
1980	25	310.300	533.965	1119.700	1908.605	
1981	60	170.900	271.091	2012.300	3178.396	
1982	63	194.000	291.499	2422.200	3605.266	
1983	84	107.800	156.260	2599.500	3702.604	
1984	84	19.800	27.680	2472.300	3407.035	
1985	84	31.200	42.322	2417.100	3231.228	
1986	84	54.300	71.724	2233.000	2891.728	
1987	84	30.000	38.397	2264.700	2832.329	
1988	84	11.800	14.554	2442.100	2940.875	
1989	84	10.100	11.958	2516.400	2924.929	
1990	66	33.300	37.921	1962.300	2209.533	
1991	48	76.300	83.871	1815.600	1989.997	
1992	48	68.600	73.820	2112.000	2260.110	
1993	36	52.300	54.696	1334.100	1395.094	
1994	36	57.300	58.589	1736.200	1775.091	
1995	24	63.400	63.400	1167.400	1167.400	
Total	1003		5212.770		42502.534	
Average Cost					42.375	
Annualized Cost/Aircraft					2.825	2.110
Annualized Cost/Wing					150.581	112.468
Total Annualized Cost/Wing	263.049					

Table 27. F/A-18E/F cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	EA-6B	Aircraft/Wing	4
Service Life	20	TAI/Wing	5.92

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1967		67.400	283.490		0.000	
1968		54.000	219.980		0.000	
1969	4	27.300	107.033	104.800	427.223	
1970	15	23.400	87.227	244.500	960.341	
1971	8	12.000	42.501	194.400	720.125	
1972	12	14.900	50.149	202.800	705.727	
1973	7	5.400	17.132	151.500	485.864	
1974	6	4.000	11.596	120.000	357.066	
1975	6	6.800	17.883	128.700	351.826	
1976	7		0.000	137.600	348.137	
1977	6		0.000	135.500	306.901	
1978	6	5.600	11.617	141.400	291.878	
1979	6	17.300	32.764	173.500	325.122	
1980	6	28.400	48.871	182.000	310.231	
1981	6	9.100	14.435	223.600	353.173	
1982	6	10.700	16.078	275.800	410.508	
1983	6	12.700	18.409	311.000	442.974	
1984	8	23.400	32.713	488.300	672.918	
1985	6	35.800	48.561	389.700	520.959	
1986	12	81.200	107.256	413.800	535.870	
1987	12	50.100	64.122	426.300	533.149	
1988	12		0.000	458.100	551.662	
1989	12	26.100	30.902	555.400	645.567	
Totals	169		1262.720		10257.223	
Average Cost					60.694	
Annualized Cost/Aircraft					3.035	4.358
Annualized Cost/Wing					17.973	25.810
Total Annualized Cost/Wing	43.783					

Table 28. EA-6B cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	S-3		Aircraft/Wing	8		
Service Life	24		TAI/Wing	11.85		

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1969		80.600	316.003		0.000	
1970		140.200	522.619		0.000	
1971		264.300	936.082	22.700	84.089	
1972	13	204.200	687.276	372.600	1296.618	
1973	35	38.800	123.093	578.500	1855.265	
1974	45	5.200	15.075	541.100	1610.072	
1975	45		0.000	557.600	1524.305	
1976	41		0.000	503.900	1274.901	
Total	179		2600.148		7645.249	
Average Cost					42.711	
Annualized Cost/Aircraft					1.780	3.739
Annualized Cost/Wing					21.080	44.288
Total Annualized Cost/Wing	65.368					

Table 29. S-3 cost breakdown in millions of FY 95 dollars.
After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	E-2C		Aircraft/Wing	4		
Service Life	17		TAI/Wing	5.92		

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1968		12.500	50.921		0.000	
1969		25.900	101.544		0.000	
1970		66.100	246.399		0.000	
1971		57.500	203.650	44.000	162.991	
1972	11	30.800	103.664	273.900	953.150	
1973	8	13.900	44.098	161.000	516.331	
1974	9	1.400	4.059	158.500	471.625	
1975	6		0.000	124.600	340.618	
1976	7		0.000	186.100	470.845	
1977	6		0.000	156.500	354.465	
1978	6		0.000	196.600	405.822	
1979	6	5.600	10.606	209.100	391.833	
1980	6	11.100	19.101	201.600	343.641	
1981	6	16.800	26.649	240.800	380.340	
1982	6	18.100	27.197	262.800	391.158	
1983	6	52.100	75.521	301.800	429.869	
1984	6	50.300	70.320	324.200	446.775	
1985	6	34.400	46.662	334.100	446.632	
1986	6	22.100	29.192	341.800	442.630	
1987	10	32.800	41.980	457.200	571.794	
1988	6	21.700	26.765	389.700	469.292	
1989	6	22.600	26.758	375.600	436.577	
1990	4	40.600	46.234	349.800	393.872	
1991	6	35.700	39.242	431.800	473.277	
1992	6	6.300	6.779	529.000	566.098	
1993		6.400	6.693	94.800	99.134	
1994		18.100	18.507	37.800	38.647	
1995	4	58.800	58.800	338.900	338.900	
Total	143		1331.341		10336.316	
Average Cost					72.282	
Annualized Cost/Aircraft					4.252	3.937
Annualized Cost/Wing					25.182	23.317
Total Annualized Cost/Wing	48.499					

Table 30. E-2C cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	SH-60B			CGTG	CVBG	
Service Life	22		Aircraft/Wing	3	5	
			TAI/Wing	4.44	7.40	

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1972		19.100	64.285		0.000	
1973		18.600	59.009		0.000	
1974		9.300	26.961		0.000	
1975		30.000	78.897		0.000	
1976		27.900	68.232		0.000	
1977		72.100	162.027		0.000	
1978		135.900	281.919		0.000	
1979		94.800	179.539		0.000	
1980		178.700	307.507		0.000	
1981		100.800	159.895	105.000	165.846	
1982	18	70.900	106.532	706.700	1051.871	
1983	27	9.000	13.046	797.200	1135.494	
1984	21	7.100	9.926	527.600	727.077	
1985	24	11.300	15.328	421.400	563.336	
1986	18	17.200	22.719	269.800	349.390	
1987	17	18.600	23.806	229.700	287.273	
1988	6	18.400	22.695	136.300	164.138	
1989	6	1.900	2.250	118.500	137.738	
1990	6	9.900	11.274	195.900	220.582	
1991	6	16.600	18.247	177.100	194.111	
1992	13	33.800	36.372	272.300	291.396	
1993	12	34.400	35.976	250.600	262.057	
1994	7	45.300	46.319	197.300	201.720	
Totals	181		1752.759		5752.027	
Average Cost					31.779	
Annualized Cost/Aircraft					1.445	2.572
Annualized Cost	CGTG				6.416	11.425
	CVBG				10.694	19.041
Total Annualized Cost	CGTG	17.841				
	CVBG	29.735				

Table 31. SH-60B cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	SH-60F		Aircraft/Wing	6	
Service Life	23		TAI/Wing	8.88	

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1984		18.500	25.863		0.000	
1985		19.100	25.908		0.000	
1986		11.600	15.322	28.400	36.778	
1987	7	4.000	5.120	165.700	207.231	
1988	18		0.000	332.500	400.410	
1989	18		0.000	373.300	433.904	
1990			0.000	111.100	125.098	
1991	18		0.000	281.000	307.991	
1992	18		0.000	254.900	272.776	
1993	12		0.000	165.200	172.753	
1994	9		0.000	42.000	42.941	
1995			0.000	7.600	7.600	
Total	100		72.213		2007.481	
Average Cost					20.075	
Annualized Cost/Aircraft					0.873	2.649
Annualized Cost/Wing					7.754	23.533
Total Annualized Cost/Wing	31.287					

Table 32. SH-60F cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Aircraft	CH-46		Aircraft/Wing	2
Service Life	33		TAI/Wing	2.96

Aircraft	Average Flyaway $	Average Procurement$	Ratio		
OH-58D	3.756	7.946	2.116		
UH-60	4.671	7.073	1.514		
SH-60B	14.000	26.914	1.922		
SH-60F	10.008	22.920	2.290		
AH-64A	8.800	12.987	1.476		
AH-64D	6.300	8.923	1.416		Average Ratio
AH-1W	4.897	9.994	2.041		1.825
CH-46	3.810	6.953			
				O&S	
Annualized Cost/Aircraft		0.211		7.929	
Annualized Cost/Wing		0.142		23.480	
Total Annualized Cost/Wing	23.622				

Table 33. CH-46 cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Military Aircraft*, 1977-1994).

Ship Class	AOE 6
Service Life	30

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1985		7.800	10.580		0.000	
1986		4.700	6.208		0.000	
1987	1	1.500	1.920	497.000	621.569	
1988		0.400	0.493		0.000	
1989	1		0.000	362.100	420.886	
1990	1		0.000	395.100	444.879	
1991		2.300	2.528	1.100	1.206	
1992		0.400	0.430	210.000	224.727	
1993	1		0.000	298.100	311.729	
Total	4		22.160		2024.995	
Average Cost					506.249	38.320
Annualized Cost					16.875	38.320
Total Annualized Cost	55.195					

Table 34. AOE-6 cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Weapon Systems*, 1977-1994).

Ship Class	CG 47
Service Life	30

Year	Quantity	RDT&E	Adjusyed RDT&E	Procurement	Adjusted Procurement	O&S
1976		18.800	45.977		0.000	
1977		14.400	32.360		0.000	
1978	1	8.600	17.840	930.000	1919.709	
1979		10.400	19.696		0.000	
1980	1	14.200	24.435	820.000	1397.746	
1981	2	4.100	6.504	1940.500	3064.989	
1982	3		0.000	2927.700	4357.666	
1983	3	3.000	4.349	2972.700	4234.172	
1984	3	1.100	1.538	2971.400	4094.837	
1985	3	36.800	49.918	2795.100	3736.546	
1986	3	35.600	47.024	2505.300	3244.356	
1987	3	25.800	33.021	2753.900	3444.144	
1988	5	110.700	136.539	4182.800	5037.096	
1989		66.200	78.381		0.000	
1990		61.900	70.490		0.000	
1991		99.400	109.263		0.000	
Total	27		677.334		34531.259	
Average Cost					1278.936	28.017
Annualized Cost					42.631	28.017
Total Annualized Cost	70.648					

Table 35. CG-47 cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Weapon Systems*, 1977-1994).

Ship Class	CVN 68
Service Life	45

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S	Refuel
1978			0.000	268.000	553.207		
1979			0.000	86.000	161.155		
1980	1		0.000	2102.000	3583.002		
1981		1.600	2.538	149.100	235.501		
1982		1.500	2.254	554.500	825.332		
1983	2	1.600	2.319	6506.600	9267.690		
1984		1.000	1.398	11.000	15.159		
1985		1.000	1.356	13.100	17.512		
1986			0.000		0.000		
1987			0.000	52.000	65.033		
1988	2		0.000	6237.000	7510.847		
1989			0.000	151.100	175.631		
1990			0.000	51.300	57.763		
1991		1.800	1.979	14.000	15.345		
1992		8.200	8.824	186.400	199.472		
1993		12.000	12.550	844.100	882.692		
1994		11.500	11.759	1210.800	1237.922		
1995		5.000	5.000	2460.800	2460.800		
Total	5		49.977		27264.063		
Average Cost					5452.813	165.551	2500.000
Annualized Cost					121.174	165.551	55.556

Total Annualized Cost	286.725

Table 36. CVN-68 cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Weapon Systems*, 1977-1994).

Ship Class	DD 963
Service Life	30

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1973			0.000	248.800	797.908	
1974	7		0.000	590.300	1756.469	
1975	7		0.000	457.100	1249.570	
1976			0.000	646.200	1634.929	
1977			0.000	186.900	423.320	
1978	1		0.000	383.500	791.622	
1979			0.000	57.800	108.311	
1980			0.000		0.000	
1981			0.000	2.200	3.475	
1982		2.000	3.005	1.200	1.786	
1983			0.000	6.300	8.973	
Total	15		3.005		6776.364	
Average Cost					451.758	22.352
Annualized Cost					15.059	22.352
Total Annualized Cost	37.411					

Table 37. DD-963 cost breakdown in millions of FY 95 dollars.
After Nicholas (*U.S. Weapon Systems*, 1977-1994).

Ship Class	DDG 51
Service Life	30

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement	O&S
1981		75.300	119.445		0.000	
1982			0.000		0.000	
1983		138.300	200.470		0.000	
1984		133.100	186.074	79.000	108.869	
1985	1	138.200	187.463	976.000	1304.736	
1986		101.400	133.938	70.400	91.168	
1987	2	91.300	116.853	1730.400	2164.111	
1988		105.300	129.878	10.400	12.524	
1989	4	37.200	44.045	2791.600	3244.807	
1990	5	105.300	119.912	3529.400	3974.073	
1991	4	101.000	111.022	3175.600	3480.632	
1992	5	92.500	99.538	4013.800	4295.279	
1993	4	110.500	115.563	3350.800	3503.997	
1994	3	102.600	104.909	2724.700	2785.733	
1995	3	91.600	91.600	2834.600	2834.600	
Total	31		1760.711		27800.529	
Average Cost					896.791	20.709
Annualized Cost					29.893	20.709
Total Annualized Cost	50.602					

Table 38. DDG-51 cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Weapon Systems*, 1977-1994).

Missile	Tomahawk
Service Life	10

Year	Quantity	RDT&E	Adjusted RDT&E	Procurement	Adjusted Procurement
1973		4.000	12.690		0.000
1974		2.300	6.668		0.000
1975		37.300	98.095		0.000
1976		130.700	319.638		0.000
1977		119.500	268.547		0.000
1978		208.500	432.524		0.000
1979		154.100	291.845		0.000
1980	6	104.800	180.340	30.200	51.478
1981	50	133.900	212.400	190.000	300.102
1982	61	144.500	217.122	232.600	346.208
1983	51	109.000	157.999	221.300	315.209
1984	124	128.600	179.783	341.700	470.891
1985	180	71.900	97.530	581.000	776.692
1986	249	59.500	78.593	692.300	896.526
1987	324	77.300	98.935	735.100	919.347
1988	475	46.300	57.107	857.200	1032.275
1989	510	56.600	67.014	696.000	808.993
1990	400	16.600	18.904	692.300	779.524
1991	648	12.200	13.411	1074.000	1177.163
1992	176		0.000	427.100	457.052
1993	200		0.000	426.100	445.581
1994	216		0.000	263.000	268.891
1995	217		0.000	305.300	305.300
Total	3887		2809.144		9351.232
Average Cost					2.406
Annualized Cost	0.241				

Table 39. Tomahawk cost breakdown in millions of FY 95 dollars. After Nicholas (*U.S. Missile Data*, 1977-1994).

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AFSAA/SAN
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Rm 1E386
Washington, DC 20330-1570

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N-81C
2000 Navy Pentagon
Rm 4A510
Washington, DC 20350-2000

13. Doctor Frank Shoup 1
Office of the Chief of Naval Operations
N-85
2000 Navy Pentagon
Rm 4A720
Washington, DC 20350-2000

14. Robert S. Wood 1
Director, Center for Naval Warfare Studies
Naval War College
Newport, RI 02841

15. Lieutenant Steven M. Williams 1
2370 Blucher Valley Rd
Sebastopol, CA 95472